J C Branner

INCENTIVES

TO THE CULTIVATION OF THE

SCIENCE OF GEOLOGY:

DESIGNED FOR

THE USE OF THE YOUNG.

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TO

THE YOUNG GENTLEMEN AND LADIES

OF THE

STATE OF NEW YORK,

Who are now prosecuting, in its numerous public and private Institutions of Learning, or in the retirement of the Family Circle, those studies which are designed to prepare them for future usefulness, wisdom, and happiness,

This Work

is respectfully inscribed, with the most sincere regards and kindest wishes for their present and future well-being, by

THE AUTHOR.

ALBANY, *May*, 1846.

INTRODUCTION.

In the preparation of the following pages, the principal object of the compiler has been, to present, from the best attainable sources, and generally in the language of the most approved and standard authors, the leading principles and prominent results of geological science, chiefly with the view of engaging the attention and attracting into this interesting channel the researches of the young. The purely scientific details and technical language, with which the practical geologist is familiar, have been, as far as possible, purposely avoided, in order to disencumber the general survey of the ample field thus opened to view, of those perplexities and embarrassments which their introduction, in the elementary stage of our inquiries, could scarcely fail to induce. Occasional repetition, in the language of different authors, of the same general principles or fundamental conclusion, will be found to occur in the progress of the work; and while no effort has been made to give to it the character of a full and scientific exposition

of geological phenomena, it is hoped that the student will be enabled to derive from it, not only a variety of useful and practical information connected with this important and attractive branch of knowledge, but those *incentives* to its further prosecution which will lead him to a more intimate and systematic acquaintance with its details. A general sketch of the geological conformation of our own continent, and more particularly of our own state, has been superadded, the materials of which were derived chiefly from those elaborate works of American geologists and naturalists, of which, even when placed by the side of the ablest European productions in this department, we have such ample reason to be proud. The prominent boundaries and most striking outlines only of the great field to which the attention of the student is here directed, have been attempted to be delineated; and if he is thereby incited to a more complete and thorough investigation of its wonders and beauty, its treasures and wealth, the object of the compiler will have been attained.

ALBANY, *May* 20, 1846.

THE

SCIENCE OF GEOLOGY.

PART I.

ORIGIN AND PROGRESS OF GEOLOGICAL SCIENCE.

GEOLOGY, in its most extended sense, has been defined to be the natural history of the earth and of the changes which have taken place and are still in progress in the organic and inorganic world. It teaches us the materials of which the earth, to a certain depth, is composed, and the order in which they are arranged; the agencies which were employed and are still in operation in the formation of its crust; the various convulsions and revolutions to which it has been and continues to be subjected; and the various races of beings which have successively inhabited its surface, during a series of epochs of unknown but long-protracted duration. It enables us to ascertain the order of succession and of time in which the various strata or formations composing the surface of the earth were deposited by the agency of water, or upheaved by the expansive power of subterranean heat—to define and describe the various phenomena which characterize these successive formations, and the particular uses to which, in the economy of nature, they may be applied.

The ancients seem to have been aware, to some extent, of the antiquity of the globe, and of the powers of natural forces in the alternate destruction and renovation of the earth's surface. Pythagoras is represented by Ovid as illustrating these general principles by an appeal to the great physical changes constantly and systematically in progress—the conversion of land into sea, and of sea into land—the excavation of valleys by rivers and floods—the growth of deltas—and the effects of earthquakes and volcanoes. Aristotle regarded the continued operation of natural agents as capable, in the lapse of ages, of effecting an entire and radical revolution in the condition of existing continents. Strabo seems to have been of opinion that all land was originally formed beneath the sea, and had been elevated, from time to time, by earthquakes; and he cites the opinions of Eratosthenes and other Greek writers as to the causes of the deposition of marine shells at great elevations and distances from the beds of the sea, at the same time insisting with great pertinency and force that the explanation of these and similar phenomena involved in the investigation should, as far as possible, be drawn from the operation of events of ordinary occurrence, such as deluges, earthquakes, and volcanic eruptions.

The Egyptian priests are understood to have maintained the aqueous origin of the globe; Thales taught that the solid materials of the earth were deposited from water; and Zeno that fire was the original material from which all things were evolved.

It is by no means unreasonable to suppose, although we have no direct evidence of the fact, that investigations of this nature occasionally occupied the attention and excited the intellect of those Grecian philosophers of a later period, who, with laborious effort and no inconsiderable success, had explored, not only the wide domain of the animal, vegetable, and mineral kingdoms, but the ampler

fields of astronomy. The observation of the transformations perpetually in progress in the natural world, and of the changes which must obviously have been wrought in the surface and general appearance of the globe, could not fail to have led their inquiring minds to the frequent consideration of the problems involved in these remarkable appearances. No traces, however, of any systematic efforts in this direction have come down to us. The Arabians, after the decline of the Roman empire, seem to have turned their attention to this subject. In the tenth century of the Christian era, Avicenna, one of the most learned physicians of his age, wrote a "Treatise on the Formation and Classification of Minerals, and the Origin of Mountains," the latter of which he attributed to the joint operation of earthquakes and the excavation of valleys by water. Omar, also, during the same century, wrote a work on the retreat of the sea—having satisfied himself by observation of the fact of important changes in this respect in the formation of the coasts of Asia.

The observations and reasoning from which the modern science of geology may be said to have originated, derived their direct impulse from the accidental discovery at Verona, in the early part of the sixteenth century, of a large number of marine shells, imbedded in the earth. The nature and origin of these fossils were warmly disputed—it being maintained, on the one hand, that they were the remains of previously-existing marine animals; and, on the other, that they were mere minerals curiously and fantastically wrought by the hand of nature in imitation of the occupants of the ocean. Some attributed their origin to the operation of fermentation by the internal heat of the earth; others to the tumultuary movement of terrestrial exhalations; and there were not wanting those who regarded them as the relics of a gigantic race of human beings formerly existing on the earth. Those who attained

to a right conception of their nature, were divided in opinion as to their origin—some attributing them to the operations of the deluge, and others to a change in the surface of the globe wrought by earthquakes, to the powerful action of running water on the land, and the gradual encroachments of the sea on the shore.

This controversy was carried on with great skill, and no inconsiderable degree of talent and ability, during the greater portion of the succeeding century. Fracastoro, Cardano, Cesalpino, a celebrated botanist, Fabio Colonna, and Steno, of Italy, Palissy, of France, and Scilla, a Sicilian painter, contended that these fossils had all belonged to animals which had once lived and multiplied where their remains were found, and demonstrated the absurdity of attributing the phenomena in question to the Mosaic deluge—an inundation, as they insisted, too transient and quiet to account for the burial of these shells at such great depths in the interior of mountains. Agricola, a German miner, Andrea Matteoli, an eminent Italian botanist, Fallopio, of Padua, and others, warmly supported the opposite hypothesis. The controversy gradually assumed a theological shape, and extended itself from the continent into England. The doctrine that these organized fossils were buried in the solid strata of the earth's surface by the Noachian deluge, came at length to be regarded as a fundamental article of religious belief. Quirini, in 1676, contended, in opposition to Scilla, that it was impossible for the diluvian waters thus to convey heavy bodies to the summit of mountains; and was the first to deny the *universality* of the deluge recorded in scripture.

Prior to the close of the sixteenth century, George Owen, an Englishman, is understood to have completed a valuable treatise, establishing the uniform succession, in a regular and methodical order, of rocks of the same geological series, through extensive tracts of country—a principle

lying at the foundation of the science, and which was not distinctly asserted or understood until after the lapse of nearly two centuries. The work of Owen remained in manuscript until subsequently to the commencement of the present century; and consequently exerted no influence upon the advancement of geological investigation and research.

Lister, toward the close of the seventeenth century, appears to have been the first to propose the idea of constructing regular geological maps—a proposition which, of itself, indicates an acquaintance with the regularity of geological structure over extensive districts. He has also the merit of having demonstrated the practicability of identifying and distinguishing strata by organic remains.

In 1680, Liebnitz published his celebrated theory of the earth, the principal features of which were, the original incandescence of the globe, its gradual refrigeration, and the condensation of its vapors into a mineral ocean; the subsequent deposition of which constituted the various kinds of sedimentary or stratified rocks, accompanied by inundations and violent convulsions: from which he proceeded to infer the double origin of primitive masses; first, by cooling after igneous fusion, and, secondly, by reconcretion from aqueous solution. These views were countenanced and adopted by Buffon and Deluc, the former of whom gave to the world his theory toward the middle of the last century.

At about this period, also, De Maillet, who had long resided in an official capacity in Egypt, from repeated observations of the occurrence of sea-shells and other marine remains on the summit of the highest mountains, inferred the original submarine formation of the existing continents, and the universal prevalence of water over the surface of the earth, from which in the progress of ages it has gradually receded. His theory was, however, very

imperfect; and, in many of its most important features, entirely baseless and visionary. Its chief value consisted in the recognition and partial development of the principle, that all our present continents were originally formed under water; from which, subsequent inquirers were enabled to proceed to a more accurate and systematic exposition of the process by which the subsequent changes were effected. Targioni and Arduino, in Italy, at about the same period, contributed essentially to the advancement of geological science; the former, by his copious observations and sound conclusions respecting the powers of rivers, floods, and the bursting of lakes, in the excavation of valleys; and the latter, by his classification of the various superficial formations into primary, secondary, and tertiary rocks. Mitchell, the Woodwardian professor, in the university of Cambridge, in England, a few years later, also, advanced many original and philosophical views on the effects of earthquakes in fracturing, contorting, and elevating, mountainous strata. Lehman, at about the same period, made a classification of the several rocks composing the earth's surface, with reference to the existence of organic remains; distinguishing all those in which these indications were uniformly absent, as primary, and all others, as secondary. Out of these, Werner subsequently formed a third class, which he denominated *transition* rocks; having observed, that between the primary and secondary rocks, there existed an intermediate group, containing, on the one hand, undoubted traces of organic remains, and on the other, obviously partaking of the crystalline character of the primary rocks, destitute of stratification, and otherwise identical to appearance, with those of the primary formations. From his observations of the structure of that portion of Saxony, in which he resided, he constructed a theory of the earth, which long maintained its ascendency throughout the

continent, and extended to England. He affirmed that the surface of the earth was composed of a certain number of layers or coats, uniformly occupying the same order with respect to each other, so that wherever one of these layers was found, the next in the ascending series would be certain to overlie it, and the one preceding it, to be found immediately beneath: that the primary unstratified rocks consisted originally of a chymical deposite from a chaotic fluid, which held their constituent elements in a state of solution; and, that as the waters of this primeval ocean gradually precipitated the minerals with which they were charged, they became adapted to the support of animal life; chymical deposites gradually ceased; crystalline rocks were no longer formed; and the secondary strata, containing the imbedded remains of animals, began to be deposited. The existence of an original chaotic fluid; the primitive nature of granite and the crystalline rocks; the original submersion under water of the entire globe; and the comparative inefficiency of the existing powers of nature to the production of the phenomena to be accounted for in the present condition and past changes of the earth's surface, constituted the prominent and fundamental doctrines of this celebrated system. By his superior acquaintance with the mineralogical characters of the rocks which came under his observation, the industry and accuracy with which he traced the distinctive peculiarities of the primitive, transition, and secondary rocks; and by the devotion and zeal with which he concentrated all his powers to the advancement and promotion of geological investigation, Werner, notwithstanding the demonstrated errors of his system, is unquestionably entitled to a very high rank among the founders and illustrators of the science. His work made its appearance, in 1787.

In the succeeding year, Dr. Hutton, a celebrated physician, of Edinburgh, published his theory of the earth; a

theory, in most respects diametrically opposed to that of his distinguished predecessor, and the ultimate establishment of which, as expanded by its author, and illustrated by Dr. Black, Professor Playfair, Sir James Hall, and others of high celebrity and scientific talent, effected a complete revolution in the fundamental principles of geological science. He taught that no geological phenomena afforded any direct evidence of the beginning of things; that the oldest rocks of which we have any knowledge are themselves but the ruins of pre-existing rocks, destroyed, or in the process of destruction or chymical change, by the slow erosion of atmospheric agency; and that the fragmentary particles thus disintegrated from the parent rock, borne by rivers to the ocean, and loosely deposited over its bed, some at greater and others at less distances, according to their weight, became at a subsequent period consolidated by heat originating in the interior of the earth, and were then upheaved and fractured by earthquakes and convulsions; that the crystalline or primary strata were originally mechanical deposites, similar to the secondary rocks, but altered by the long-continued action of heat; while granite had crystallized from a state of fusion, and had slowly cooled under great pressure; in short, that all the revolutions which have visited the earth, were but the result of the ordinary operations of nature continued through very long periods of time; that what is now sea was formerly dry land; and that, by the action of running water, materials are constantly accumulated on the bed of the sea, to produce the strata of new continents, which, by new convulsions similar to those that have already occurred, will again, in process of time, be uplifted and laid bare, while that part of the earth now inhabited will be again submerged. "The object of this theory," observes Playfair, "was, not to explain the origin of things, but the consideration of those

changes which the earth has undergone, through the agency of known causes, since the establishment of the present order; and the first general fact remarked by its author, was the formation of a great portion of the crust of the globe out of more ancient materials, and that all the stratified rocks consisted of the remains of other strata more ancient than themselves. The greater part of the present continents, therefore, having once existed in a sedimentary form, at the bottom of the sea, must have been consolidated by subterranean heat; the stratified rocks, which, instead of being horizontal in position, are inclined, or vertical, inflected, broken, and found detached from each other at various elevations, and sometimes at the greatest heights above the sea, must have been elevated by the expansive power of heat; veins, whether metalliferous or stony, injected by a similar process, subsequently to the formation of the strata which they intersect; and mineral bodies subjected, when exposed to the influence of the air, to change, decomposition, and decay, and their fragmentary particles to transposition, by the action of the rivers to the sea. From these considerations, the alternate and probably repeated dissolution and renewal of all mineral substances, may be inferred." From the effect of compression, united with the agency of heat, Hutton conceived himself enabled to explain the consolidation of the sedimentary rocks; to disprove the existence of primitive mountains; to demonstrate the igneous origin of the granitic and trappean masses; to show that they have, at various times, broken through and invaded the sedimentary strata, and to establish the hypothesis that this agency is an essential part of the constitution of the globe. That granite and the other massive rocks are the result of simple fusion; that all, or a great proportion of the stratified rocks are sedimentary; that they have been indurated and elevated, and the plu-

tonic masses violently injected among them by a force acting from below, is now regarded as fully established; and that this indurating and elevating power resembles what we term internal heat, whatever be its nature or cause, has been shown with a degree of probability nearly equivalent to demonstration.

Prior to this period, the existence of marine deposites at the tops of the highest mountains, the inequalities on the earth's surface, and the marks of violent action which have dislocated and upheaved its solid strata, were almost universally referred to the operation and effects of the deluge, combined with the subsequent encroachments of the sea, the overflowing of lakes, the devastations of avalanches and glaciers, the sand-floods of tropical climates, and the desolating effects of earthquakes and volcanoes. In his "Dissertation on the Theory of the Earth," read to the Royal Society of Edinburgh, in the spring of 1785, Dr. Hutton explicitly renounced the attempt to reconcile the phenomena of geology with the idea of the recent creation of the world, and endeavored, from the present state of our globe, to trace the causes which have operated in past ages, and may reasonably be presumed to continue to operate in all future time. Conceding the comparatively modern appearance of man, as the inhabitant of the earth, he demonstrates that the inferior species of animals, particularly those inhabiting the ocean and its shores, must have had a long preceding existence. "We find," he observes, "the marks of marine animals in the most solid parts of the earth: consequently these solid parts have been formed after the ocean was inhabited by those animals which are proper to that fluid medium."—"The world which we inhabit," he continues, "is composed of the materials, not of the earth which was the immediate predecessor of the present, but of the earth which, in ascending from the present, we consider as the third, and

which had preceded the land which was above the level of the sea, while our present land was yet beneath the waters of the ocean. There are three distinct, successive periods of existence, and each of these is, in our measurement of time, a period of indefinite duration."

Dr. Hutton first announced and clearly demonstrated the important principle that all the hard substances of the mineral kingdom, when elevated into the atmosphere, have a tendency to decay, and are subject to a disintegration and waste, to which no limit can be set but that of their entire destruction; that no provision is made on the surface for repairing this waste, and that there no new fossil is produced; that the formation of all the varied scenery which the surface of the earth exhibits, depends on the operation of causes, the momentary exertions of which are familiar to us, though we knew not before the effect which their accumulated action was able to produce. Water, he conceives, was first employed to deposite and arrange, and then fire to consolidate, mineralize, and lastly to elevate the strata; but with respect to the unstratified or crystallized substances, he recognised the action of fire only.

"The circumstance, however, which gives to this theory its peculiar character," observes Professor Playfair, "is the introduction of the principle of pressure to modify the effects of heat when applied at the bottom of the sea, confining the volatile parts of bodies exposed to the action of subterranean fire, and forcing them, in many instances, to undergo fusion, instead of being calcined or dissipated by burning. Combustion and inflammation are chymical processes, to which other conditions than the presence of a high temperature are required. The state of the mineral regions makes it reasonable to presume that these conditions are wanting in the bowels of the earth, where, of consequence, we have a right to look for nothing but expansion and fusion, the only operations which seem essen-

tial to heat, and inseparable from the application of it, in certain degrees, to certain substances."

It has been objected to Dr. Hutton, that he ascribed too much to the agency of running water, and that he referred the formation of valleys to rivers alone. On the contrary, he distinctly recognises the operation and joint result of three different causes—a regular stratification of materials—subterranean heat—and the agency, on the surface, of the sun and air, wind and water, rivers, currents, and tides. In the destructive and decomposing agency of these elements, he also recognised the forces by which the elevated lands were gradually worn down, and transferred by rivers to the bottom of the sea; in the volcano and the earthquake, the energy of that subterranean power which indurated and again elevated the submarine deposites—while its effects were displayed in the frequent emergence of new islands, the formation of new mountains, and the repeated elevation and depression of extensive tracts of land. "The ruins of an older world," he observes, "are visible in the present structure of our planet; and the strata which now compose our continents have been once beneath the sea, and were formed out of the waste of pre-existing continents. The same forces are still destroying, by chymical decomposition, or mechanical violence, even the hardest rocks, and transporting the materials to the sea, where they are spread out and form strata analogous to those of more ancient date. Although loosely deposited along the bottom of the ocean, they become afterward altered and consolidated by volcanic heat, and then heaved up, fractured, and contorted." He had convinced himself of the igneous origin of basalt and trap rocks, and of their ejection in a melted state through fissures in the older strata; and attributed the compactness of these rocks, and their different aspect, when compared with that of ordinary lava, to their having cooled down under the pressure of the sea.

While the claims of this theory were undergoing a strict examination in Edinburgh, Mr. William Smith, in England, was engaged in a careful and thorough examination of strata and fossils, from which he deduced the most ample confirmation of the theory of Lister, above referred to, that certain groups of fossils were peculiar to certain strata, and that by organic remains alone, independently of mineral composition, the true order of succession of rocks was determinable.

Toward the close of the eighteenth century, the idea of distinguishing the mineral masses into separate groups, and of studying their relations, began to be generally diffused. Among the most celebrated of those whose labors at this period contributed to this end, were Pallas and Saussure; the former of whom, after an attentive examination of the great mountain-chains of Siberia, deduced the general principles which, as he conceived, governed the formation of chains composed chiefly of primary rocks, and in his travels in different portions of the Russian empire, adduced many sound geological observations relative to the more recent strata of the earth's surface, and the former prevalence of the sea over the existing continents. Saussure employed the chief portion of his time in studying the geological structure of the Alps and the Jura; and, without deducing any general system, or originating any new or peculiar views, furnished ample and valuable materials for his successors in this fertile field of labor.

These researches were followed up by the establishment, in 1807, of the London Geological Society, which gave a new and most effective impulse to the prosecution of the science. The study of organic remains, and the careful examination and classification of the various strata, now began to occupy the attention and engage the labors of individuals of the most commanding and extensive scientific acquirements.

Cuvier and Brongniart, in France, followed up the researches which had thus been instituted, by a thorough investigation of the fossil remains of the great Parisian basin. The *tertiary* formations, although affording some of the most interesting phenomena of geological science, and occupying a large portion of the existing surface of the earth, had hitherto received no attention at the hands of geologists. They were now thoroughly explored, and found to throw great light on the distribution of land and water, during an epoch comparatively recent—to furnish an assemblage of plants and animals more nearly approaching those of contemporary origin; and by the evidence which they afforded of the slow process by which they must have been elaborated, to accumulate additional proof of the great antiquity of the earth. The formations of the Paris basin were found to consist of an alternation of marine and fresh-water strata, from the latter of which innumerable bones of *mammalia*, of extinct races, were derived. In his geological and zoological researches, Cuvier carried us back to those early periods of the history of our planet when man had as yet no existence, and a succession of strange and monstrous beings occupied its habitable surface. From his researches and those of his contemporaries and successors, it appeared that there was a period when the earth consisted of a solid mass of granite, covered with water, and destitute equally of vegetation and of life; that this state of things was succeeded first by one in which zoophytes, mollusca, and reptiles, abounded, and vegetation rankly flourished; then by a condition of the strata which admitted of the existence of enormous animals, like the leviathan and behemoth; and subsequently, and at a considerably later period, of animals and plants similar to those now existing, and of which man was a contemporary. It is only after the last deluge, and in the more superficial strata formed since that event, that the

remains either of man or of the existing races of animals have been discovered: clearly indicating, so far as we possess any geological evidence of the facts, that neither of these previously existed in the countries which they now inhabit. It is not impossible, however, geologically considered, that man *may* have had a prior existence, and that the regions inhabited by him may now lie at the bottom of the ocean; or that earlier traces of him may yet be discovered. All that is meant to be here asserted is, that hitherto no such evidence has been adduced.

"The progress of geology, from the period at which it began to assume the systematic character of a regularly-digested science," observes Mr. Conybeare, in an able report on this subject at the second meeting of the British Association, "may be considered as having presented three marked stages, distinguished by three successive schools. Each of these schools has selected, for the more especial object of its attention, a single member of the three great geological divisions in the series of formations, viz., the primitive, secondary, and tertiary; and the succession of these schools has, by a singular coincidence, followed the same order with that of the formation to which they were devoted. It may also be observed that the leaders of each school have been distinguished geologists of three different nations—Germany, England, and France. The first, or German school, is that of Werner: this directed its attention principally to the primitive or transition formation, in which the distinctions of mineralogical character assume the greatest importance, and the imbedded minerals, from their variety and relations to the rocks containing them, became the chief objects of the geologist's notice. The second, or English school, has distinguished itself by the ardent and successful zeal with which it has developed the whole of the secondary series of formations: in these the zoological features of the organic remains associated in the

several strata afford characters far more interesting in themselves and important in the conclusions to which they lead, than the mineral contents of the primitive series. This school generally recognises the masterly observations of Smith, first made public in 1799, as those which have principally contributed to its establishment; although the regular distribution of organic remains had before been recognised in Italy by Steno, and in France by Rouelle: and although Werner in his lectures and Saussure appear to have indicated generally that the laws of this distribution bore a relation to the geological age of the formations containing them, yet a degree of vagueness hung over the whole subject, which precluded any extensive or useful application of this great principle, until the acute observations of Smith first brought it prominently forward in all the precision of exact detail, as applied to a vast succession of formations, including the most important portion of the geological series; and as, from his situation in life, we must consider the discoveries of Smith as the extraordinary results of native and untaught sagacity of intellect, they must, on this account, be held to challenge a still warmer tribute of approbation, and may be regarded as strictly original in him, even where faint traces of anticipation may be found in continental writings, little likely to have fallen beneath his observations. The third school, or that of tertiary geology, owes its foundation to the admirable 'Memoir on the Basin of Paris,' published by Cuvier and Brongniart in 1811. The high scientific distinction of Cuvier, and the striking and interesting nature of the facts developed in his brilliant memoir, excited a marked sensation, and commanded the general attention of men of science: for none such could peruse with indifference those masterly descriptions, which exhibited the environs of one of the great metropolitan cities of Europe as having been successively occupied by oceanic inunda-

tions and fresh-water lakes; which restored from the scattered fragments of their disjointed skeletons the forms of those animals, long extinct, whose flocks once grazed on the margins of those lakes; and which presented to our notice the case of beds of rock, only a few inches in thickness, extending continuously over hundreds of square miles, and constantly distinguished by the same peculiar species of fossil shells. The public mind being thus fully awakened to a perception of the vast importance of zoological geology, as superadded to mineral geology, became thus ripely prepared to appreciate the value of the materials previously collected by the unassisted acuteness and industry of Smith, which had illustrated the whole secondary series of formations in the same spirit as Cuvier and Brongniart had applied to a portion of the tertiary class; and which thus, after an interval of neglect, assumed their just place and rank in the geological system. From this period the views of the zoological school were universally adopted by the most active and efficient laborers in the progress of English geology, and were by them, from to time, greatly extended. The establishment of the Geological Society of London afforded also, about the same time, a central point of reunion to those engaged in this pursuit; an establishment eminently calculated to stimulate their endeavors, by the promotion of mutual intercourse, and the comparison of the information individually obtained—a point in every science very important, but most emphatically indispensable in one which can never be effectually advanced without the steady co-operation of numerous independent observers."

The researches of geologists have, within the last half century, created a new department of knowledge, which, in point of philosophic importance and scientific interest, is unsurpassed by any other. They demonstrate the surface of our planet not merely to have existed, but to have

undergone physical changes similar in kind, if not in degree, to those which affect it at present, and to have been tenanted by a long succession of animals and vegetables for countless ages before the traces of man and his works present themselves to the most searching investigation. "Geologists now no longer," observes Sir John Herschel, in his admirable "Discourse on the Study of Natural Philosophy," "indulge fanciful theories, either with reference to the original formation of the globe, or its subsequent transformation—such as a change of the axis of rotation of the earth, causing an influx of the sea upon the land—the attraction of the waters of the ocean, by the sudden approach of comets—a long succession of tremendous and ravaging catastrophes and cataclasms—epochs of terrific confusion and violence—and the sudden application of convulsive and fracturing efforts—but rather aim at a careful and accurate examination of the records of its former state, which they find indelibly impressed on the great features of its actual surface, and to the evidences of former life and habitation, which organized remains, imbedded and preserved in its strata, indisputably afford. Such records teach us that the whole or nearly the whole of our present lands and continents were formerly at the bottom of the sea, where they received deposites of materials from the wearing and degradation of other lands not now existing, and furnished receptacles for the remains of marine animals and plants inhabiting the ocean above them, as well as for similar spoils of the land washed down into its bosom. The examination of these remains affords indubitable evidence of the former existence of a state of animated nature widely different from the present, and of a series of periods of unknown duration, anterior to that in which it has been the habitation of man, in which both land and sea abounded with forms of animal and vegetable life, which have successively disappeared and given place

to others, gradually approximating to and comprehending existing species. The successive deposition of the strata in which these remains are found, are characterized by peculiarities sufficiently definite to enable us to recognise those of the same period, in every part of the world." From these appearances we may reasonably infer that, for a long period, the earth's surface was adapted only to vegetables and the lowest grade of animal life; afterward to animals of an amphibious nature, and such as could exist only in the neighborhood of lakes or inland seas; and that this state of things was gradually succeeded by another adapted to a higher order of existences. The changes at that portion of the surface preceding the tertiary formation of the geologist were attended by the introduction of a gigantic class of animals now mostly extinct; while the subsequent extension and diffusion of alluvial matter seems to have been admirably adapted to the growth of plants and the existence of animal life. Between these successive changes long intervals appear to have elapsed. We find, too, that strata, which must have been originally horizontal and continuous, have undergone great dislocations and rupture: and we are thence led to consider, not only the adequacy of aqueous and volcanic causes, separately, or in combination, to the production of these results, but the causes to which we may reasonably ascribe the form and position of the inert materials of the earth, and the nature and distribution of its animal and vegetable productions.

The means of observing and recording the prominent features of the interior structure of the earth to a greater depth than would otherwise have been accessible, are furnished by the inclined position which a large portion of the stratified rocks have been made to assume in consequence of the violent and sudden displacements to which they have from time to time been subjected by the opera-

tion of internal heat. In addition to the facilities afforded by this disposition of the materials entering into the composition of the earth's surface, artificial excavations of every description, inland precipices, rocky promontories and headlands rising along rivers, lakes, seas, and oceans, the sides of mountains in the vicinity of valleys, defiles, and gorges—the accumulated ruins at their base, and those which have been transported frequently to a great distance by the action of diluvial and glacial currents—offer abundant opportunities for the prosecution of investigations of this nature. Volcanic eruptions in various parts of the globe have, at different periods of the earth's history, thrown up the formations of the abysses below, revealing to our view the primitive rocks of igneous origin—the granites, syenites, porphyries, serpentines, soapstones, and trap, which constitute the foundation upon which the superincumbent materials composing the surface of the earth, repose; and satisfactorily accounting for the various disruptions, displacements, transpositions, and alterations, in the otherwise orderly succession of strata.

The crust of the earth is of a thickness not yet accurately estimated. The deepest mine known is but about one thousand yards in depth; while the thickness of the primitive range of formations only has been estimated by the most competent judges at not far from sixty miles. The surface only of the earth, to a depth not exceeding twelve feet, is destined to the support of life and vegetation, and two thirds of this surface is at present occupied by water.

The average depth of the ocean has not as yet been satisfactorily ascertained; but from the best sources of information in our power, we have reason to conclude it exceeds four miles. The highest mountains of the globe do not attain an elevation of five miles. With reference, therefore, to the entire diameter of the earth, the rind to the orange, or the coat of varnish to a terrestrial globe of the

ordinary size, seem, in the existing state of our knowledge, not unapt illustrations of that portion of the solid contents of our planet which fall within our direct comprehension. And yet, from these apparently scanty materials, the researches of science, and the results of continuous and systematic observation and induction, have constructed a body of facts which, extending indefinitely into the past, and comprehending the successive periods of mineral, vegetable, and animal creation, enable us freely to peruse the legible records of an antiquity so vast as to be well nigh inconceivable, and to trace, in "characters of living light," the whole subsequent history of our planet.

"By these researches into the strata of the earth," observes Mr. Lyell, "we acquire a more perfect knowledge of its present condition, and more comprehensive views concerning the laws now governing its animate and inanimate productions. The form of a coast; the configuration of the interior of a country; the existence and extent of lakes, valleys, and mountains, can often be traced to the former prevalence of earthquakes and volcanoes in regions which have long been undisturbed. To these remote convulsions, the present fertility of some districts, the sterile character of others, the elevation of land above the sea, the climate and various peculiarities, may be distinctly referred. On the other hand, many distinguishing features of the surface may often be ascribed to the operation, at a remote era, of slow and tranquil causes, to the gradual deposition of sediment in a lake or in the ocean, or to the prolific increase of testacea and corals."

It was not until the year 1807, that any effort worthy of notice was made for the development of American mineralogy or geology. In that year, William McClure, who had previously examined and explored most of the

great geological fields of Europe, commenced, single-handed, the Herculean task of tracing out and delineating the great features of our rock-formations, which he at length, patiently and perseveringly accomplished, having crossed the Allegany mountains in no less than fifty different places. In 1816, Professor Cleaveland published his work on mineralogy and geology; and, in 1818, the American Journal of Science, a work which, up to the present period, has so essentially and perseveringly contributed to the elucidation and development of every branch of natural science, was established by Professor Silliman. In 1824, Professor Eaton completed a survey of the entire route of the Erie canal, under the direction and at the sole expense of the Hon. Stephen Van Rensselaer, of Albany. Since that period, most of the state governments have authorized and prosecuted, through the agency of the most scientific geologists and naturalists, full geological surveys of their respective territories: embracing in the aggregate an area of upward of seven hundred thousand square miles; and including, in many instances, zoological, botanical, chymical, paleontological, and topographical information of the greatest value and importance.

PART II.

GENERAL PRINCIPLES OF GEOLOGY.

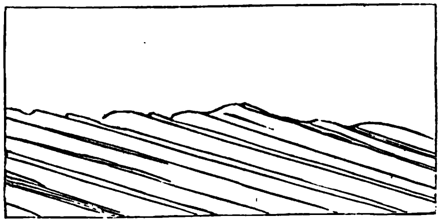
THE principal elements of geological science are the extent of the formations of which it treats; their arrangement into layers or strata; the mineral character of the rocks of which they are composed; and the fossil organic remains which abound in all except the lowest strata.

"Our present continents, with their mountains, were formed at the bottom of the ocean; and our hardest rocks were once sand, and gravel, and mud—derived from the wearing down of land no longer in existence. Land has been converted into sea, and sea into land, and land again into sea. The same portions of the earth's surface have been subjected to repeated oscillations, so as to be alternately above and below the ocean level. As the various strata and collections of strata are not continuous over all the earth, but local, interrupted, confined in point of space, and separated from each other by intervening strata, and formations of a different character on the same plane, the probability seems to be that they never formed one continuous synchronic deposite over the whole surface of the earth; but took place successively, as the causes preceding and producing them were in readiness for the exertion of their force."

The leading doctrines which distinguish the geology of the present day are,

1. That of the sedimentary origin of the stratified

rocks, and the existence of natural formations, or groups of strata in a certain order of superposition.



The germ of this great doctrine is believed to have originated with Lehman; but its principal developments, in connexion with the important principle that the groups of secondary and tertiary strata are distinguishable by the fossils which they respectively contain, are due to the investigations of William Smith, toward the close of the last century, in England, and of Cuvier and Brongniart, soon after the commencement of the present century, in France.

2. That of the igneous origin of the unstratified rocks, and of the injection of matter in a state of fusion at various and repeated epochs, among the sedimentary strata, producing a variety of changes in their structure and appearance.

It is now regarded as established that the earth was either originally in a fluid state, or that, after the formation of its material substratum, the whole of it was reduced to a fluid state by heat, while revolving on its axis, therefore, it would necessarily assume, as the result of the mutual attraction of its parts and of its rotatory motion, its present form of an oblate spheroid, flattened at the poles, and bulging out at the equator. By the slow and gradual disengagement, in the form of gaseous vapors,

of this intense heat, the surface is supposed, in process of time, to have cooled and indurated, surrounded on all sides by an atmosphere, composed of that portion of the gaseous substances generated by these exhalations which had not been precipitated in the shape of water. From the phenomena presented by the transition strata, it seems probable that at this early period the globe was encircled with this latter element.

The crust of the earth is found, as has been heretofore stated, to be composed of certain contiguous layers or strata, each distinguishable from the other, and in their relative arrangement, following a fixed order. Some of these strata are, in particular localities, wanting; and they vary considerably in depth. The aggregate thickness of these layers is commonly estimated at ten miles; and it is only by the outlying of their edges, in different localities, and at different elevations, their mineral character, and the fossils which they respectively contain, that we are enabled to ascertain the series to which they belong, their relative age, and the nature of their formation. The order of superposition which the entire strata, composing the earth's surface, ordinarily present, is frequently interrupted: strata belonging to a particular period of time and order of succession, being absent; as, for instance, in our own country, portions of the secondary and tertiary formations of Europe, which, there is reason to believe, never had an existence with us: and other portions in different localities, washed away by deluges and floods: but the strata, of recent formation, are never found underneath those of an older date. Granite, and formations of igneous origin, constitute, as will hereafter be seen, an exception, under certain circumstances, to this general principle.

Notwithstanding subsequent dislocations, from cataclysms or other causes, may frequently have contributed to

interrupt the continuity of strata over wide surfaces, the general feature by which they are distinguished, in every region of the globe, is confined *locality*, and *successive*, rather than simultaneous deposition. In some districts, large masses, consisting of numerous strata, have been apparently rent asunder, and assumed different relative elevations, by the depression of one portion, or the upheaving of another, so that the same strata, instead of presenting a continuous development, are found at different heights. In others, we find entire ranges of mountainous formations, thrown out of the perpendicular, and inclined at a considerable angle, the result, apparently, and probably, of sudden and powerful dislocation, by the action of subterranean convulsions.

One of the fundamental propositions of modern geology consists in the doctrine of the *elevation of the land*, in opposition and contradistinction to the *lowering of the sea*. As the science advanced, it became evident that certain portions of the globe had been alternately sea and land; then perhaps an estuary, gulf, or bay; then sea again; and lastly, once more habitable land: having remained in each of these conditions for considerable periods of time; while, on the other hand, there is no evidence from human experience of a *lowering of the general level of the sea* in any region: nor can the waters of the ocean sink in one place without a general depression of their level throughout the globe.

The tests of relative age, and the means of identifying contemporaneous portions of the same groups in the aqueous classes of rocks, are superposition, mineral character, and fossils: the uppermost in a series of horizontal strata being the most recent, and the lowest the most ancient; so that, to use the beautiful illustration of Mr. Lyell, "a series of sedimentary formations are like volumes of history, in which each writer has recorded the annals of his

own times, and then laid down the book, with the last written page uppermost upon the volume in which the events of the era immediately preceding were communicated. In this manner a lofty pile of chronicles is at length accumulated; and they are so arranged as to indicate, by their position alone, the order in which the events recorded in them have occurred." The adoption of this principle of superposition is one of the chief characteristics of modern geology; and much of the astonishing progress of the science during the last half century may be ascribed to its continued application. It has been ascertained, by the most extensive examination, that while the same fossils prevail through very considerable spaces in a horizontal direction, we seldom meet with the same remains *vertically*, or in a line transverse to the stratification, for many fathoms together, however similar, in a mineralogical point of view, may be the composition of the beds. "These facts," observes Mr. Lyell, "have led to the conviction that at successive periods of the past, the same area of land and water has been inhabited by species of animals and plants as distinct as those which now people the antipodes, or which now coexist in the arctic, temperate, and tropical zones. It appears that, from the remotest periods, there has ever been a coming-in of new organic forms, and an extinction of those which pre-existed on the earth—some species having endured for a longer, others for a shorter time—but none having ever reappeared after once dying out. And this circumstance it is which confers on fossils their highest value as chronological tests."

The agency both of fire and water in the formation of the rocks which compose the crust of the earth is now universally conceded, as well as the fact that a similar process is now in course of operation for the production of similar results. The materials thus produced are known to be arranged in a determinate order. The masses of

granite on which they rest were once unquestionably in a state of igneous fusion; and are by some regarded as having, by a slow and gradual progress, cooled on the surface of an incandescent globe, and by others as the fused and reconsolidated materials of older sedimentary strata; their base consists of crystalline masses, frequently piercing through the superincumbent beds, passing by insensible gradations of composition into known igneous products, and producing the same effects on the sedimentary rocks with which they come in contact.

These granite rocks are succeeded in the order of superposition by crystalline strata, destitute, like them, of organic remains, and exhibiting indications of sedimentary deposites. They graduate, on the one hand, into the slate series, of decided aqueous formation; and, on the other, into granite rocks, apparently of igneous origin. Their origin is by some referred to the decomposition and degradation of the first granite crust, and the absence of organic remains is accounted for by the uncongenial condition of the primitive ocean in which they were deposited to the sustentation of living beings of any kind; while others suppose that such remains may have originally existed—the relics of a former period—and that they disappeared during the process of fusion to which the earlier fossiliferous strata were subjected, and which resulted in the formation of granite.

These formations are succeeded by a vast series of stratified rocks similar in their composition to the aqueous deposites now in process of formation at the mouths and deltas of large rivers and in the beds of inland seas, abounding with shells and corals, and containing plants and other terrestrial remains, swept down from the land; each series affording unquestionable evidence of having successively constituted the bed of the sea, and exhibiting the organic forms which were in existence during its deposition. This

series has been divided by geologists into distinct groups, distinguished by peculiarities of fossil remains, presenting in general a marked analogy to existing races, though susceptible of distinct classification in the minor details of their structure and organic formations. Many of the remains found in the lowest of these strata are of an entirely different race from any now existing; and the resemblance to existing genera and species is gradually discoverable in the ascending order of the series. That the composition of these rocks, thus produced by the deposition of the crumbling fragments of an older series, and their arrangement into successive and numerous layers—the growth of the organic remains which they contain—the alternations of sandstones with clay and limestones—of lava-currents with aqueous deposites—of strata enclosing trees, the accumulated vegetation of centuries of extraordinary fertility, with others of maritime origin—must have been the result of ages upon ages preceding the appearance of the human race upon the globe, must be conceded by all. "When we trace numerous repetitions of these alternations," observes Mr. Trimmer, "through formation after formation, and system after system; when we see that rocks formed by this slow process have been consolidated and broken up—their fragments, containing fossil remains, reconsolidated into conglomerate rocks—those conglomerates again broken up and again consolidated; and lastly, when we contemplate the gradual change of organic types from the oldest to the most recent strata, every candid inquirer must admit that the few thousand years during which the human race has been placed upon the earth, dwindle into insignificance compared with the time required for this succession of events." Nor does this view of the subject at all conflict with the sacred records of creation, when examined in the genuine spirit of sound Christian philosophy, unfettered by preconceived opinions.

The greater part of the dry land whose structure has hitherto been investigated is found to be composed either of the fossiliferous strata above adverted to, or of igneous rocks which have burst through them; and from the broken, contorted, and inclined appearance of these strata, their elevation above the bed of the sea, where they were originally deposited, is clearly attributable to the effect of subterranean forces, which, acting along certain lines and in a determinate direction, have suddenly, violently, and at successive epochs, upheaved those igneous rocks which constitute the central axis of the existing mountain-chains; while, by a more general and perhaps gradual expansion, other extensive strata, containing organic remains, have been raised often to great heights above the level of the sea, with very slight disturbance of the horizontal position in which they were originally deposited. The subterranean forces thus operating in the production of existing continents and mountain-chains, are evidently of the same nature with those which in a modified sphere are concerned in the production of the varying phenomena of earthquakes and volcanoes.

The various attempts which have from time to time been made to frame a theory of the earth, have brought into view two diametrically opposite opinions: the one representing the course of nature as uniform, from the beginning of time to the present day—the causes operating in the production of change having acted with equal intensity at all periods of the earth's history; the other accounting for the present condition of things by the intervention of sudden and violent catastrophes, and the operation of agents of a more powerful nature, both in kind and in degree, than any with which we are now acquainted. "Geologists who held the latter opinion, maintained," observes Mr. Whewell, in his "Philosophy of the Inductive Sciences," "that the forces which have elevated the Alps

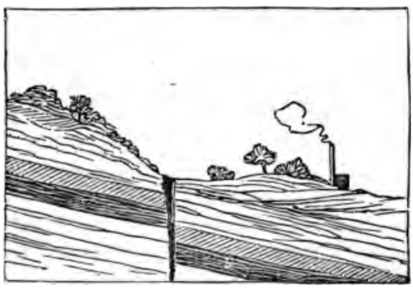
or the Andes to their present height, could not have been any forces which are now in action; they pointed to vast masses of strata, hundreds of miles long, thousands of feet thick, thrown into highly-inclined positions, fractured, dislocated, crushed; they remarked that upon the shattered edges of such strata they found enormous accumulations of fragments and rubbish, rounded by the action of water so as to denote ages of violent aqueous action; they conceived that they saw instances in which whole mountains of rock, in a state of igneous fusion, must have burst the earth's crust from below; they found that, in the course of the revolutions by which one stratum of rock was placed upon another, the whole collection of animal species which tenanted the earth and seas had been removed, and a new set of living things introduced in its place; finally, they found above all the strata vast masses of sand and gravel, containing bones of animals, and apparently the work of a mighty deluge. With all these proofs before their eyes, they thought it impossible not to judge that the agents of change by which the world was urged from one condition to another, till it reached its present state, must have been more violent, more powerful, than any which we see at work around us. They conceived that the evidence of catastrophes was irresistible." This formidable array of proofs has, however, in the judgment of by far the greater number of the most eminent modern geologists, been met and overcome by showing, to use the language of the same author, "that the sudden breaks in the succession of strata were apparent only—the discontinuity of the series which occurred in one country being removed by terms interposed in another locality; by urging that the total effect produced by existing causes, taking into account the accumulated result of long periods, is far greater than a casual speculator would think possible; by making it appear that there are, in many parts of the world, evidences of a slow and

imperceptible rising of the lands, since it was the habitation of now-existing species; by proving that it is not universally true that the strata separated in time by supposed catastrophes contain distinct species of animals; by pointing out the limited fields of the supposed diluvial action; and finally by remarking that, though the *creation* of species is a mystery, the *extinction* of them is going on in our own day. Hypotheses were suggested by which it was conceived that the change of climate might be explained, which, as the consideration of the fossil remains seemed to show, must have taken place between the ancient and the modern times. In this manner, the whole evidence of catastrophes was explained away; the notion of a series of paroxysms of violence in the causes of change, was represented as a delusion arising from our contemplating short periods only in the action of present causes: length of time was called in to take the place of intensity of force; and it was declared that geology need not despair of accounting for the revolutions of the earth, as astronomy accounts for the revolution of the heavens, by the universal action of causes which are close at hand to us, operating through time and space, without variation or decay." It was, moreover, urged that it is highly unphilosophical to assume that the causes of the geological events of former times were of a different kind from those now in action, provided the latter are in themselves adequate to explain the facts. Alternations of activity and repose in volcanoes, and the occasional intervention of earthquakes, deluges, and storms of unusual or long-protracted violence, may indeed be called in to vary the uniformity of existing elements of change; but these are agents of whose existence and power we are fully aware; and they are therefore not to be included among those extraordinary and inconceivable catastrophes which are resorted to by the advocates of the doctrine above referred to.

It is conceded on all hands that the *strata* of the earth's crust were deposited under water as soft sediment, accumulated layer upon layer, and then hardened by a natural process into rock. First and deepest, we find beds of the rock called gneiss, composed of the same elements, essentially, with granite, on which it rests, and to the flexures and cavities of which it fits so accurately, as to evince its deposite in a soft, semi-fluid state. Its elements are changed, in shape and disposition, from those which compose the granite, precisely as might be expected from the action of water in suspending, floating, and then precipitating them in laminæ and beds of greater thickness. Over the gneiss come the beds of mica-schist and slate, evincing the same fact of deposite from suspension in a fluid. The same observations apply to the numerous beds of siliceous, slaty, and limestone aggregates, the sandstone, chalk, and clay, and finally to the beds of detritus and alluvium constituting the tertiary series and the formations above them.

An examination of the earth's surface shows that it is formed of numerous layers or strata of rocks, for the most part horizontally disposed, the greater portion of which contain fossil organic remains, chiefly of marine origin; from which the inference is irresistible that the ocean must, at some former period of considerable duration, have covered the highest existing mountain-peaks on which these remains have been found. Many of the more ancient strata have, by the operation of subterranean convulsions, been thrown, as has heretofore been remarked, into a highly-inclined and sometimes nearly vertical position. Upon these, subsequent formations have accumulated, presenting the appearance of horizontal strata resting upon inclined. The rocks composing these various formations are not only of different composition, but contain the remains of races of animals and species of plants distinct

as well from each other as from those now known to be in existence. There are between thirty and forty distinctly-defined layers or strata of different mineral structure, lying upon each other, and so arranged as to occupy a certain and uniform order of succession. All the members of this order are not, indeed, to be found in any particular locality, but the *order of position* is never violated. Any member, or several members of the series, may be absent; but the residue will uniformly be found to retain their relative position, with reference to the whole, in precisely the same manner as though the entire series were present. Mountain-ranges frequently consist of a ridge of subjacent rock, on which occur, on each side, sloping strata. This ridge is technically termed an *anticlinal* line, the sloping strata of which present their *escarpments* or steep edges to this axis. In mining countries, the veins containing the ore usually compose a system of parallel and nearly-vertical partitions in the rock, and are frequently intersected by another system of veins parallel to each other, and nearly perpendicular to the former. *Faults* or *fissures* ofter present themselves, where the rock on one side appears to



have been originally a continuation of that on the other

and to have been subsequently shoved aside, or up and down. In addition to these larger fractures, rocks occasionally exhibit the phenomena of *joints*, or a tendency to separate in particular directions, and of a slaty *cleavage*, in which the parallel subdivisions produce a succession of *laminæ* of indefinite thinness.

The agency employed in elevating the solid framework of the earth, above the level of the ocean, and giving to it those various modifications of surface of such paramount importance to organic nature, are, first, the expansive power of internal heat; and, secondly, the action of water, constantly engaged in decomposing its prominent parts, and redistributing their materials in stratified beds within the valleys scooped out by its course. These antagonizing forces originally produced, and continually maintain, that endless variety of form and composition in the mineral masses of the earth's surface to which its animal and vegetable inhabitants are so greatly indebted. The one has given origin to that series of rocks which are unstratified and crystalline, having been protruded in a state of igneous fusion: the other has given rise to the immense aggregation of stratified and alluvial rocks, composing the greater part of its dry surface, although from the marine remains they contain, it is clear they have mostly been deposited beneath the ocean, and subsequently elevated by the expansive power of subterranean heat. Two theories contend for the explanation of this latter force—that of central heat, which supposes the nucleus of the globe to have always been at an intense temperature, and probably fluid; the cooling of the surface having first formed the solid crust, and then in its inward progress broken and convulsed it; and the chymical theory, which supposes the nucleus to be composed of the metallic bases of the earth; the phenomena of heat, eruptions, and elevatory expansions, being caused by

the oxydation of these substances by water or air penetrating through clefts in the superficial rocks. That this powerful subterranean agency is the same in substance which characterizes the phenomena of thermal springs and volcanoes, and of the protrusion of granite and trap rocks, is understood to be universally conceded; as also, that its generation is due to the expansive power of that heat to which the crust of the earth is everywhere more or less subjected. Its general and constant action is amply attested by the prevalence of incandescent lava beneath the apertures of volcanoes; by hot springs and discharges of steam from the minor fissures of the earth; by the appearances of fusion which the crystalline rocks present; and by the gradual increase of temperature perceptible in mines, in descending below the surface. At this point, however, opinions widely diverge; and no sufficient data yet exists for the satisfactory solution of this perplexing problem. "We are, therefore, obliged," says Mr. Trimmer, "to rest satisfied with the knowledge of the undisputed fact, that the solid crust of the earth is subject to the more or less constant and general communication of intense heat from below, whereby many of the rocks of which it is composed, are variously altered in their mineral composition and character—expanded, fractured, displaced, and protruded, sometimes in a solid, sometimes in a liquefied state, at a white heat; and in that state discharging various gases and vapors." The changes now constantly occurring on the earth's surface, are unquestionably attributable both to igneous and aqueous agency. Among the former, are to be classed the earthquake and the volcano; and among the latter, the action of frost, rain, torrents, rivers, waves, and currents, in wearing away the solid parts of the earth, and in carrying off and depositing the matter thus abstracted, at the bottoms of rivers, valleys, the beds of lakes, or the

floor of the ocean. Basalt, and the other trap rocks, are so similar in structure, with the lava ejected from volcanoes, as to leave no doubt of their origin from the action of subterranean fire. The experiments of Sir James Hall, in this interesting department of geological and mineralogical inquiry, have shed a flood of light on the principles connected with igneous action, under great pressure.

"From a careful study of the effects of heat under different circumstances," says Mr. Phillips, in his Treatise on Geology, "it seems probable that the granitic rocks, which are the lowest of the primary series, owe their present condition and appearance to the effect of general or partial fusion. Above this granitic series, we find the effects of water. Many of the primary, therefore, and all of the secondary rocks, owe their present appearances and arrangements to the action of water—exhibiting the results both of agitated and of tranquil waters; mechanical aggregates, sedimentary deposites, and chymical precipitates, in frequent repetition. This circumstance, combined with the discoveries of organic remains, teaches us, that, during a long period, the sea flowed, rich in living beings, over rocks which contained no relics of life—varying its deposites at different periods, yet preserving a general conformity of arrangement from the oldest to the most recent, and a similarity over large regions. The aquatic animals and other remains which are entombed in the earth, exhibit a long series of beings whose origin dates from some of the earliest strata, and whose forms, differing according to the antiquity of the rocks, successively approach the modern productions of the land and the ocean. During this process, at intervals, vegetable forests, swept into estuaries or lakes, furnished the materials of coal, and the intermitting action of submarine volcanoes frequently broke the consolidated strata, and

formed basaltic and other overlying rocks. At times, too, more violent exertions, probably of the same nature, uplifted groups and ranges of mountains with great disruption and dislocation. Those operations appear, however, to have been gradually weakened: and when the last series of the secondary beds, partly marine and partly lacustrine, was deposited, a large portion of the rocks previously consolidated became tenanted by land animals. But again the waters returned, and overflowed the inhabited world, removed rocks, excavated valleys, and destroyed the terrestrial inhabitants."

"I concur," observes Baron Cuvier, "with the opinion of M. De Luc and Dolomieu, that if there be anything determined in geology, it is that the surface of our globe has been subjected to a vast and sudden revolution, not further back than from five to six thousand years; that this revolution has buried, and caused to disappear, the countries formerly inhabited by man, and the species of animals now most known; that, on the other hand, it has left the bottom of the former sea dry, and has formed upon it, the countries now inhabited; that, since this revolution, those few individuals whom it spared, have been spread and propagated over the lands newly left dry, and consequently, it is only since this epoch that our societies have assumed a progressive march, formed establishments and combined systems. But the countries now inhabited, and which the last revolution left dry, had been before inhabited, if not by mankind, at least by land animals; consequently, one preceding revolution, at least, had overwhelmed them with water; and, if we may judge by the different orders of animals whose remains we find therein, they had, perhaps, undergone two or three irruptions of the sea."

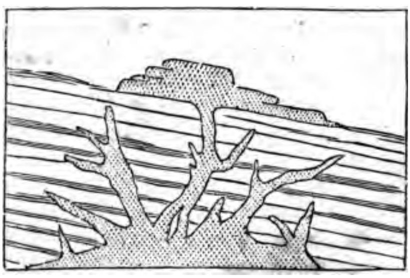
An able writer in the Southern Review, for Nov., 1831, speaking of the last of these great irruptions, says, "How

came these waters so suddenly to overflow? Did the moon change her relative position as to the earth, or was the direction of the pole altered, with respect both to the sun and moon, so as to whelm that portion of land beneath the sea, which had been previously inhabited, and by placing this region at the same time more remote from the influence of the sun, bind it thenceforward in perpetual ice? That some such event did occur, and that it must have been caused by some such extraordinary means, we can not doubt. May not this have been the time, supposing man to have previously existed, when the pole of the earth's axis became inclined to the plane of the ecliptic, and the change of season commenced, the earth not being habitable but in part, before this? May not the then habitable part of the earth have enjoyed a more delightful climate than the present, on that very account? And may not this superior climate have been the cause of the longevity of the antediluvian? There is nothing very improbable in the suggestions."

The unstratified rocks of igneous origin consist of a variety of minerals, chiefly crystallized, and which appear to have been formed by fusion of the original mass of which they were composed. In some instances, the instrumentality of both igneous and aqueous agency is manifest, the rock having apparently been originally formed in strata or layers, and subsequently crystallized by the action of subterranean heat. Mr. Lyell denominates this description of rock *metamorphic* or *altered*. Unstratified rocks are generally divided into three distinct classes—plutonic, trap, and volcanic. The plutonic rocks are those which appear to have been formed by the action of intense heat at a great depth in the interior of the earth, and to have gradually cooled under the pressure of the superincumbent rocks. The principal rock belonging to this class is granite. Until recently, this rock was be-

lieved to be more ancient than any of the stratified formation; but it is now ascertained that granitic veins have, at different eras, subsequent to the deposition of the superincumbent strata, forced their way upward, through masses of overlying granite, and stratified rocks containing organic remains; and it usually happens in such cases that the intensely-heated granite is found to have wholly or partially dissolved these rocks, and thus rendered them metamorphic. Trap rocks are formations chiefly derived from volcanoes long since extinct; and the difference in composition and appearance between these and the rocks termed basaltic and volcanic, has been generally attributed to the different manner in which they were cooled; the former being supposed to have been deposited at the bottom of the ocean, and the latter on land, where, by exposure to the atmosphere, it has been hardened and condensed.

Igneous rocks are frequently found interspersed among the primary stratified rocks, in many parts, beds and veins of granite passing up into the superincumbent deposites.



Rocks belonging to the trap formation have also forced their way among these stratified rocks, either in irregu-

lar masses of great extent, or in large and consolidated veins or dikes.

"The crystalline formation," says Mr. Lyell, "such as granite and gneiss, were termed primitive and primary, by some of the earlier observers, because in each district they are the lowest in geological position. It is now understood, in regard to granite, syenite, and the unstratified class, that they are of various ages, often newer than fossiliferous strata, and that it by no means follows that they were first in the order of time, because they are inferior in position. Paradoxical as the first statement of this proposition appears, it is now acknowledged that the superstructure is often older than the foundation on which it rests, the latter having been forced up subsequently from below, either in a solid form, or more frequently like lava in a volcano. It is also now admitted, in direct contradiction to all preconceived opinions, that many stratified hypogene formations, the gneiss, mica schist, talcose schist, and saccharine marble of the Alps, Apennines, and other districts, have assumed their crystalline texture, after the origin of many of the fossiliferous strata, even in some cases, long after the deposition of those which repose directly upon them. Nevertheless, if we confine the term primary to all rocks which we can prove to be of *older date than strata in which* organic remains have yet been discovered, and all the crystalline rocks found for a considerable space on every side of the points where the lowest strata charged with fossils are incumbent upon the non-fossiliferous formations, we shall be liable to little error.

"However firmly we may be convinced that subterranean causes, connected with the development of internal heat, have operated with great and perhaps nearly uniform intensity at each successive geological period of equal duration, we must still be prepared to find that by

far the largest portions of the visible hypogene rocks are of high relative antiquity to the fossiliferous deposites. This must happen, if we are correct in assuming that the crystalline rocks, whether stratified or unstratified, have been formed originally, at considerable depths in the crust of the earth: for in that case, a long period of time must have elapsed after their origin, before they can have been brought up within the sphere of human observation. There must have been great upheaval and denudation to cause them to emerge, even in a single district; but it must require a series of geological epochs before those formed at a given era of the past can have become generally exposed at the surface. A repetition of one series of elevatory movements after another must have taken place in different areas, accompanied by denudation; and while such forces are acting, the deposition of new strata is going on, and the pre-existing crystalline rocks are becoming relatively rude and more ancient."

The primitive chains of mountains are believed to be parts of the solid nucleus of the earth, upheaved by the earthquakes and volcanoes, which then shook the globe. Cuvier, Buckland, and other eminent geologists, are disposed to attribute these phenomena to the operation of convulsions far more powerful than any which are now active on the surface of the earth, and believe that the internal fires by which they were produced have in a great measure spent their forces, and are no longer capable of producing equal changes in future. Mr. Lyell, and the disciples of Hutton, on the other hand, assert that natural agents are now in operation—such as earthquakes, volcanoes, rivers, inundations, &c., fully competent to the accomplishment of these results in the past history of the globe, and to the production of future revolutions of equal magnitude and importance and requiring the presence of equal energies. The broken and uneven character of the

secondary strata, and the projection through them of portions of the primary, are supposed to indicate the frequency of these convulsions at the period of their formation; while the presence of marine deposites in the upper series show a renewed return of the ocean over the land, destroying its existing inhabitants, and remaining for a sufficient length of time to permit the deposition of the secondary, and part of the tertiary strata, when its recession is again indicated by the remains of terrestrial animals of a more perfect organization than any which had yet appeared.

"From the remotest epoch in the earth's physical history recognisable by man," observes Mr. Mantell, in his Wonders of Geology, "to the present time, the mechanical and chymical laws which govern inorganic matter appear to have undergone no change. The wasting away of the solid rocks by water, and the subsequent deposition and consolidation of the detritus by heat; the subsidence of the dry land beneath the sea, and the elevation of the ocean bed into new islands and continents; the decomposition of animal and vegetable substances on the surface, and their conversion into stone or coal, under circumstances in which the gaseous principles were confined; the transmutation of mud and sand into rock, and of earthy minerals into crystals; these physical changes have constantly been going on under the influence of those fixed and immutable laws established by Divine Providence, for the maintenance and renovation of the universe."—"If we extend our views beyond the limits of strict induction, and venture to speculate on the condition of our globe in the dawn of its existence, the theory of Liebnitz, which assumes the original *nebular* condition of the solar system, a former incandescent state of this planet, and its gradual refrigeration seems to be the only

hypothesis in harmony with the present state of astronomical and geological science."

This hypothesis has been adopted by some of the most eminent philosophers of modern times. It accords with the astronomical speculations of Sir William Herschel and La Place, respecting the condensation of the solar system from a state of gaseous expansion—has been adopted by Cordier as an explanation of volcanic phenomena, and by Fourier from mathematical calculations, and the rate of increase of the internal temperature of the earth in proportion to its depth. Humboldt has defined volcanic action as the influence exerted by the interior of the planet on its external covering during the different stages of refrigeration; and Elie de Beaumont has connected the doctrine of secular refrigeration with his theory respecting the elevation of contemporaneous mountain-chains. This theory embraces the following points:—

1. That in the history of the earth, long periods of comparative repose, during which the deposition of sedimentary matter went on in regular continuity, have been interrupted by short periods of paroxysm and violence;

2. That during each of these periods of disturbance, a great number of mountain-chains have been suddenly formed;

3. That all the chains of each paroxysmal period have a uniform direction—being parallel, or nearly so, to each other, and to a great circle of the sphere, while those of different periods are parallel to different circles;

4. Each period of disruption has accorded with a great change in organic types;

5. These paroxysmal disturbances, which have recurred at intervals from the remotest geological periods, may be renewed, and the existing state of repose broken by the sudden elevation of other parallel chains of mountains;

6. That it is probable that one of these convulsions has

occurred within the historic era, when the Andes were upheaved to their present height: that chain appearing to be the last elevated—being the best defined and least obliterated feature on the present surface of the globe;

7. That the instantaneous upheaving of great mountain-chains from the ocean must cause a violent agitation of the waters; and the rise of the Andes may perhaps have produced the transient deluge noticed among the traditions of all nations; and—

8. That these successive revolutions are not the results of ordinary volcanic action, but may depend on the secular refrigeration of the heated interior of our planet.

The doctrine of secular refrigeration affords a probable explanation of many geological phenomena, such as the universal prevalence of granite and the crystalline stratified rocks; the temperature of the earlier climates as evinced by organic remains; the general diffusion of that high temperature, and its gradual decrease in later periods: while the several mountain-chains by which the surface has successively been ridged; the long periods of ordinary action, separated apparently by short intervals of disturbance, and accompanied by irruptions of the sea over the land—may all be attributed to the fracture and collapse of the external crust, accommodating itself to the contracting dimensions of the cooling nucleus.

Granite is the fundamental rock on which all the other known rocks rest: although, from the dependence of fissures filled with the richest deposites of ore on the proximity of granitic and other porphyritic rocks, it is evident that the substances which compose the materials of the trap and volcanic rocks ejected to the surface are deeply seated below the granite.

The series of rocks containing organic remains is found to rest upon rocks which are destitute of them, and which bear evident traces of fusion. Such are the lowest rocks

with which we are acquainted. Lower still, subterranean fires are in full activity, giving rise to volcanoes and earthquakes; and from the great areas over which the shocks of the latter are simultaneously felt, we may reasonably infer that the source of internal fire is deeply seated. The mean density of the earth has been ascertained to be twice as great as that of the rocks at its surface; and supposing the interior to be composed of materials equally compressible with those of which the crust consists, the pressure to which the central parts are subject would cause the mean density to be much higher than it is found to be. A large portion of the interior must, therefore, it is inferred, be occupied by cavities, or must consist of less compressible materials than the rocks at the surface—or there must be some expansive force within, capable of counteracting the effects of pressure. Central fire may be, and probably is, this counteracting force.

Mr. Lyell seems inclined to favor a theory which attributes the folded and contorted structure of many of the mountain-chains, such as those of the Alleganies and others, to the subsidence, or sinking downward, rather than the expansion or forcing upward of a portion of the earth's crust. This hypothesis he regards as "simply a modification of one very popular with the earlier geologists, who ascribed the fractured condition of the most ancient rocks to the shrinking of the supposed original fluid nucleus of the planet, it being assumed that the earth passed gradually from a state of fusion by heat to a solid condition. It was truly remarked that, during the process of congelation and contraction, the incumbent strata, or those first solidified, would sink and accommodate themselves to a narrow area, viz., the circumference of a spheroid of smaller diameter, and according to their different degrees of pliability or hardness, the beds would be bent or broken. When this theory was first propounded, all the disturb-

ances of the rocks were referred to a remote geological era, and supposed to have been nearly simultaneous. We have now ascertained that, on the contrary, they have been produced at a great variety of successive epochs, and that some mountain-chains are very modern in the earth's history in comparison with others. Nevertheless, the hypothesis may in a limited sense be quite sound: for we may imagine one part after another of the subjacent nucleus, underlying the thin coating or crust which we explore geologically, to be melted by volcanic heat, and after expansion, to cool and become again consolidated, and collapse. The rocks would undergo some disturbance when they were first uplifted; but when the heat was withdrawn, and contraction took place, there would be a still greater amount of dislocation, crumpling, and folding of the beds. All the elaborate mechanical explanations resorted to in illustration of the doctrine of a general contraction, and a diminution in the size of the entire planet, may be applicable to the phenomena of strata, whether in plains or mountains, which have at successive periods become contorted within limited areas. We have only to substitute the partial liquefaction of the interior of the earth at moderate depths, for the primitive fusion of the entire incandescent nucleus, and to suppose that each local development of subterranean heat was followed by refrigeration, and we then discover a cause fully adequate to produce the fracture, plication, and lateral pressure of rocks, at as many successive periods of the past as the facts now established in geology require.

"Nearly all mountain-chains can now be shown to have been like the Apalachians, of later date than the creation of organic beings. We also know that at each geological period characterized by the appearance of distinct races of living beings, the earth's surface, although for the most

part tranquil, has been in some regions the theatre of volcanic eruptions."

The temperature of the earth's surface depends principally upon the influence of the sun, modified by various other causes, such as elevation above the mean level of the sea, distribution of land and water, and nature of the surface. At a certain depth, nowhere exceeding one hundred feet, the variations of solar heat are unfelt, and a constant temperature prevails, which is about the same as that of the mean temperature of the surface. Below this point it appears, from experiments made on the temperature of deep mines, and on the waters of Artesian wells, that, as we descend, the water, rocks, and air, grow continually warmer to the comparatively small depths which have as yet been reached by man. The mean rate of increase is estimated by Cordier at one degree of Fahrenheit for every fifteen yards of depth.

Mr. Lyell is of opinion that instead of assuming the theory of original central heat, it would be more in accordance with ascertained facts to refer the interior heat of the earth to chymical changes constantly in operation beneath the surface; the general effect of chymical combination being the evolution of heat and electricity, which in their turn become sources of new chymical changes. The existence of currents of electricity in the shell of the earth has been deduced from the phenomena of terrestrial magnetism; from the connexion between the diurnal variation of the magnet and the apparent motion of the sun; from observations on the electro-magnetic properties of metalliferous veins; and from atmospheric electricity continually passing between the air and the earth. Subterranean electric currents may, therefore, in his judgment, exert a slow, decomposing power, like that of the voltaic pile, and thus become a constant source of chymical action, and consequently of volcanic heat. He also suggests that the met-

als of the earth and alkalies may exist in an oxydized state in the subterranean regions, and that the occasional contact of water with these metals must produce intense heat; that the hydrogen evolved during the process of saturation may, on coming afterward in contact with the heated metallic oxydes, reduce them again to metals; and that this circle of action may be one of the principal means by which internal heat and the stability of the volcanic energy are preserved.

Conceding the igneous fusion of the interior mass, the occasional admission of water, its decomposition into its constituent elements, oxygen and hydrogen, and the violent agency of steam will in his judgment abundantly account for those volcanic ejections, earthquakes, disruptions, displacements, deluges, and cataclysms, which must have been of great frequency and violence during the early part of the earth's existence, and while its crust was comparatively thin: and which seem to have been continued, in fearful succession, within the period to which history and tradition extends. The two hundred volcanoes known to have been in occasional activity within that period, including in this estimate those in the Pacific ocean and in the eastern archipelago, serve, in this view of the subject, as outlets to the vapors and gases, which would otherwise produce the same kind of devastations to which the surface of the globe furnishes so many indubitable attestations. The primary causes of the volcano and the earthquake are, to a great extent, the same, and are doubtless connected with the passage of heat from the interior to the surface of the earth.

The bottom of the former ocean must, according to this theory, have been raised by a force underneath, similar to the action of water let into the igneous abyss, and suddenly decomposed, or converted into steam. "These upheavings do not appear to have been simultaneous through the

whole earth, but to have happened frequently, first in one part, then in another, according to the subterraneous locality of their causes. The islands in the Grecian archipelago enumerated by Pliny, and subsequently Stromboli, Lipari, and Volcano, in Italy, were doubtless produced in this manner. Instances of volcanic eruption at the bottom of the ocean are not unfrequent. From the discovery of numerous strata of marine deposites above ancient beds of lava, and of others intermixed with isolated fragments of volcanic substances, it has been reasonably inferred that these fires must have commenced when their source was below the surface of the water. The consequence of this upheaving of parts of the ocean's bed, at various times and in various places, was, the throwing of the ocean-waters with great force and violence over the adjacent regions, producing those numerous deluges, cataclysms, and debacles, which rendered the granitic region fit for future vegetation. To this cause is likewise to be attributed the various granitic peaks and high mountains, and the marks of destructive subversion so fatal to the original plants and animals of a former world, and the deluges of such frequent occurrence in the early history of the globe."

Von Humboldt, in his remarks on the linear distribution of volcanoes, seems to have regarded them as *vents* placed along the edge of vast fissures, communicating with reservoirs of igneous matter, and extending across entire continents. He observed, also, the intimate connexion and frequent apparent sympathy of the action of volcanoes and earthquakes.

From existing volcanic vents, in conjunction with those now extinct or dormant, and from the evidences of regularly-increasing heat in all the rocks, until we reach the region of permanent internal fires, varying in position and intensity, we arrive by an intelligible process at the igneous origin of the primary or unstratified rocks of granitic

structure. Ascending in the chronological order of the strata, we next reach the formations containing the fossil remains of the marine animals which occupied the earliest seas of whose existence we have any traces. Following the continued succession of their developments through the range of stratified rocks replete with the evidences of animal and vegetable life, each series presenting a distinct and clearly-marked character, we finally reach the present order of things—the commencement of the historical era—the last in the order of creation. "We have accomplished," says Mr. Whewell, "a vast store of facts of observation, and have labored with intense curiosity, but hitherto with very imperfect success, to extract from these facts a clear and connected knowledge of the history of the earth's changes. Nearly the same was the condition of astronomy at the time of Kepler, when the accumulated observations of twenty centuries resisted all the attempts of that ingenious man and his contemporaries to construct a science of physical astronomy. But, though checked by such failures, they were not far from success: and when, for the next succeeding century, philosophers had employed themselves in creating a distinct science of dynamics, the science of physical astronomy, full and complete, made its appearance, as if it were a matter of course, and thus showed the wisdom of separately cultivating the study of causes and the classification of facts."—"Of late years," he continues, "an opinion has taken root among us that the dynamics of geology must invoke the aid of mathematical reasoning and calculation, as the dynamics of astronomy did at the turning point of its splendid career. Nor can we hesitate to accept this opinion, and look forward to the mathematical cultivation of physical geology as one of the destined stages of our progress toward truth."

"The supposition," observe the same author in another place, "that there are, beneath the crust of the terrestrial

globe, liquid or semi-liquid masses which exert a pressure upward, leads to the inquiry, what phenomena of fissure, disruption, and dislocation, this subterranean strain would produce? The answer to this inquiry must be given by mathematical reasoning from mechanical principles."

The attention of geologists is now also powerfully directed to the results of microscopic analysis, "revealing to us," says Professor Silliman, "the intimate and concealed structure of fossil plants—of petrified trees, whose delicate vessels had been filled with mineral matter—siliceous, calcareous, or metallic—or whose substance had been converted into coal—the fibres and tissues of primeval forests converted into stone. The microscope, in the hands of Ehrenberg, of Berlin, and others, has penetrated the veil which concealed the fossilized races whose existence had not even been suspected—the thousands of millions of animalcules which, encased in shields of flint, people the dimensions of a single cubic inch. In the same manner, the vast beds of tertiary, of chalk, and many of the secondary limestones, disclose, under the searching scrutiny of the microscope, a world of minute organic forms, that once lived in that earlier ocean by whose waves their elegant structures were first sustained, and then broken down and comminuted into an earthy, calcareous powder, almost impalpable to the naked eye."

"Natural history and natural theology," observes an able writer in the London Quarterly Review, "had hitherto been confined to but *one volume* of Nature's works—that which relates to the present order of existence. Geology has discovered in the bowels of the earth, and published, a *series of preceding volumes*—more or less injured and imperfect, it is true—but all written in the same hand, bearing the manifest impress of the same mighty mind—and equally abounding in new and vivid proofs of the wisdom and goodness of their Author." It has been shown,

to use the language of one of the most eminent and distinguished of modern geologists, Mr. Lyell, that "the earth's surface has been remodelled again and again; mountain-chains have been raised or sunk; valleys formed, filled up, and then re-excavated; sea and land have changed places: yet throughout all these revolutions, and the consequent alterations of local and general climate, animal and vegetable life has been sustained: this has been accomplished without violation of the laws now governing the organic creation, by which limits are assigned to the variability of species. The succession of living beings appears to have been continued, not by the transmutation of species, but by the introduction into the earth, from time to time, of new plants and animals; and each assemblage of new species must have been admirably fitted for the new states of the globe, as they arose, or they would not have increased and multiplied, and endured for indefinite periods."

From the phenomena presented by the structure of the older rocks, we may infer the existence and occurrence of a train of events, which, although utterly destructive to all kinds of life, nevertheless prepared the earth for the reception of living beings. "Those ingredients of the crust of the earth," observes Professor Daubeny in a late lecture, "which seem designed more especially for the purpose of living beings, may be distinguished into such as minister to some object of utility, for man in particular, and such as are essential to animals and vegetables in general. The former class, being commonly more or less poisonous, occur in veins, for the most part existing in the older rocks, being stored, as it were, out of the way, before living beings were created. Such are copper, tin, lead, mercury, and other of the metals. The latter, on the contrary, are more generally diffused through the strata of the globe, although for the most part in comparatively minute proportions. Among the latter are the fixed alkalies, which

are present in all rocks of igneous origin, from which they are slowly disengaged by the action of air and water in proportion as they are required for the necessities of living beings."

Modern discoveries prove, not only that the existing species of animal and vegetable life had a comparatively recent origin, but that they were preceded by several other systems and species, each of which must have had a commencement and a termination. Through this series we are conducted back to a period anterior to the earliest, in which we find a series of primary strata wholly destitute of organic remains; and from this circumstance we infer their deposition to have preceded the commencement of organic life. "In the most ancient condition of land and water," observes Dr. Buckland, "geology refers us to a state of things incompatible with the existence of animal and vegetable life; and thus, on the evidence of natural phenomena, establishes the important fact that we find a starting-point, on this side of which, all forms, both of animal and vegetable beings, must have had a beginning."

In the original granitic formation, or first hardened crust of the earth, no remains, either of animal or vegetable life, marine or terrestrial, have been discovered; and the legitimate presumption is that neither existed. In the transition strata, however, immediately succeeding, the remains of zoophytes, and other marine animals of the lowest grade, begin to appear. At the commencement of the secondary strata, plentiful indications of vegetation are presented, and vertebrated animals began to exist, among which were enormous crocodiles, turtles, fish, &c.; and this seems to have been the period when the primitive mountains were formed by the violent upheaving of the solid granite, by the expansive force of internal heat. In this elevated position, they became exposed to all the varieties of atmospheric action, constantly exerted in re-

ducing them again under the dominion of the ocean; in separating and disintegrating their materials; and depositing them in a lower position, whence, by the action of floods and water courses, they were carried to the ocean and distributed at various depths over its surface to be again consolidated by interior heat and reproduced at the surface by the agency of the same powerful forces. The bottom of the sea appears to have been the great laboratory where the loose and floating materials, detached from the primitive granite were mineralized, and the atmosphere, the region where these are again decomposed and resolved into their constituent elements. "The decomposition of all mineral substances exposed to the air," observes Professor Playfair, "is continued, and is brought about, by a multitude of agents, both chymical and mechanical, of which some are known to us, and many, no doubt, remain to be discovered. To the various aeriform fluids which compose the atmosphere, must be added moisture, heat, and perhaps light; substances, which, from their affinities to the elements of mineral bodies, have a power of entering into combination with them, and of thus diminishing the forces by which they are united to one another. By the action of air and moisture, the metallic particles, particularly the iron, which enters in great abundance into the composition of almost all fossils, becomes oxydated in such a degree as to lose its tenacity, so that the texture of the surface is destroyed, and a part of the body resolved into earth. Some earths, again, such as the calcareous, are immediately dissolved by water; and though the quantity so dissolved be extremely small, the operation by being continually renewed, produces a slow but perpetual corrosion, by which the greatest rocks must, in time, be subdued. The action of water, in destroying hard bodies into which it has obtained entrance, is much assisted by the vicissi-

tudes of heat and cold, especially when the latter extends as far as the point of congelation; for the water, when frozen, occupies a greater space than before; and if the body is compact enough to refuse room for this expansion, its parts are torn asunder by a repulsive force acting in every direction. Water appears as the most active enemy of hard and solid bodies; and in every state, from transparent vapor to solid ice; from the smallest rill to the greatest river, it attacks whatever has emerged above the level of the sea, and labors incessantly to restore it to the deep. The parts loosened and disengaged by the chymical agents, are carried down by the rains, and in their descent, rub and grind the superfices of other bodies. Thus water, though incapable of acting on hard substances by direct attrition, is the cause of their being so acted on; and when it descends in torrents, carrying with it sand, gravel, and fragments of rock, it may be truly said to turn the forces of the mineral kingdom against itself. Every separation which it makes is necessarily permanent; but the parts once detached can never be united, save at the bottom of the ocean.

"The consequence of so many minute, but indefatigable agents, all working together, and having gravity in their favor, is a system of universal decay and degradation, which may be traced over the whole surface of the land, from the mountain top to the seashore. Where the seacoast is bold and rocky, its broken and abrupt contour, the deep gulfs and salient promontories by which it is indented, and the proportion which these irregularities bear to the force of the waves, combined with the inequality of hardness in the rocks, prove that the present line of the shore has been determined by the action of the sea. The naked and precipitous cliffs which overhang the deep, the rocks hollowed, perforated as they are further advanced in the sea, and at last insulated, lead to the

same conclusion, and mark, very clearly, so many different stages of decay. The fragments of rock, when detached, become instruments of further destruction, and make a part of the powerful artillery with which the ocean assails the bulwarks of the land; they are impelled against the rocks, from which they break off other fragments, and the whole are thus ground against one another; whatever be their hardness, they are reduced to gravel, the smooth surface and round figure of which are the most certain proofs of a detritus which nothing can resist. Where the coast is flat, we have abundant evidence of the degradation of the land, in the beaches of sand and small gravel; the sand-banks and shoals that are continually changing; the alluvial land at the mouth of the rivers; the bars, that seem to oppose their discharge into the sea; and the shallowness of the sea itself.

"It is highly interesting to trace up, in this manner, the action of causes with which we are familiar, to the production of effects which, at first, seem to require the introduction of unknown and extraordinary powers; and it is no less interesting to observe how skilfully nature has balanced the action of all the minute causes of waste, and rendered them conducive to the general good. Of this, we have a most remarkable instance in the provision made for preserving the soil, or the coat of vegetable mould spread out over the surface of the earth. This coat, as it consists of loose materials, is easily washed away by the rains, and is continually carried down by the rivers into the sea. This effect is visible to every one; the earth is removed, not only in the form of sand and gravel, but its fine particles, suspended in the waters, tinge those of some rivers continually, and those of all, occasionally, that is, when they are flooded or swollen with rains. The quantity of earth thus carried down

varies according to circumstances. The soil, therefore, is continually diminished; its parts being transported from higher to lower levels, and finally delivered into the sea. But it is a fact that the soil, notwithstanding, remains in quantity, the same, or at least, nearly the same; and must have done so ever since the earth was the receptacle of animal or vegetable life. The soil, therefore, is augmented from other causes, just as much, at an average, as it is diminished by that now mentioned; and this augmentation, evidently can proceed from nothing but the constant and slow disintegration from the rocks. In the permanence, therefore, of a coat of vegetable mould, on the surface of the earth, we have a demonstrative proof of the continual destruction of the rocks; and can not but admire the skill with which the powers of the many chymical and mechanical agents employed in this complicated work are so adjusted as to make the supply and the waste of the soil exactly equal to one another. The great quantity of round and hard gravel, often to be met with in the soil, under such circumstances as prove that it can only have come from the decomposition of rocks that once occupied the very ground over which this gravel is now spread, clearly evinces the former existence of immense bodies of strata in situations from which they have now entirely disappeared.

"Some of the modes of aqueous action," observes Professor Whewell, "are destructive, as when rivers erode the channel in which they flow, or when the waves of the ocean by their perpetual assault shatter the shores and carry the ruins of them into the abyss of the ocean. Some operations of the water, on the other hand, add to the land, as when deltas are formed at the mouths of rivers, or calcareous springs from deposites of travertine. Even when bound in icy fetters, water is by no means deprived of its active power; the glacier carries into the

valley masses of its native mountain, and often floats, with a lading of such materials, far into the seas of the temperate zone. It is indisputable that vast beds of worn-down fragments of the existing land are now forming into strata at the bottom of the ocean."

The study of deposites formed by rivers, including the general effects of running water, on the land, as a destroying and renovating agent, the chymical effects of atmospheric action and of water on rocks; together with the erosive action of rivers on their beds and shores, constitutes an important part of geological investigation. "The excavation of valleys," says Mr. Trimmer, "seems to be a complex result of the various forces which have acted on the surface of any given region both before and after its emergence from the ocean." There are several classes of valleys, in the formation of which, different agencies have manifestly prevailed; such as oceanic valleys, formed beneath the sea; longitudinal valleys, like those of the Alps, arising out of the line of junction of two separate and distinct formations; valleys of disruption, like some of the great transverse valleys of the same chain produced by upheaving forces; valleys of elevation, where the strata, protruded and pushed upward, dip in opposite directions from the axis of elevation; valleys of denudation, in which strata nearly horizontal, and once continuous are now separated by a wide excavation; and valleys of erosion, deep gorges, excavated entirely by the long-continued action of water; although, in general, rivers have not formed the valleys through which they flow.

"The action of running water, on the land, has a constant tendency to reduce the inequalities of its channel, by cutting down obstructions, filling up hollows, and removing the detritus from higher to lower levels. The coarser fragments are generally deposited in lakes or valleys, or spread over plains; but a vast amount of highly

comminuted matter is held in suspension till it reaches the sea, and is deposited where the tides and freshets meet, there to form new stratified deposites, charged with animal and vegetable remains, which, in future ages, may in their turn, be reconverted into land."—"Mountain torrents, whose course to the sea is short, hurry into it a confused mass of fragmentary matter, and then form deposites resembling some of the older conglomerates. But longer rivers deposite their gravel and sand during the earlier parts of their course, some portions of which are arrested by lakes and others deposited by inundations on the surface of valleys and alluvial plains. Many level surfaces, traversed by a river and surrounded by ranges of hills, may be mistaken for the sites of lakes, while they are in reality, valleys partially filled with detritus."

"The motions produced in the waters of the ocean by tides and currents, exercise a powerful influence upon the land. The waste of a coast produced by this action is more or less rapid in proportion to its exposure to the effects of the waves, the nature of the strata, and the hardness or softness of the rocks of which it is composed.

"The materials derived from the wasting of the land are distributed by the agitation of the waves, according to their magnitude and specific gravity; the larger and heavier fragments remaining upon the beach till they are ground into coarse sand; while the smaller are more widely diffused by the action of currents."

"The beds of rivers and oceans," observes Sir John Herschel, "are constantly receiving the *debris* produced by the action of water upon the surfaces of rocks; springs are depositing large quantities of calcareous and other matter; and volcanoes pouring over considerable districts immense streams of lava. It may, therefore, be deduced from analogy, that the same causes which are now in operation produced the same or similar results in

the composition of those masses which form the framework of our globe. The relative changes in the distribution of land and water on the surface of the earth are produced so slowly, that they frequently pass unnoticed, from generation to generation; and yet, the mighty changes which they are effecting, may ultimately give a new character to the physical appearance of the globe. Heat, air, water, and chymical action, co-operate both in the destruction and recomposition of the rocks which form the earth's surface. Of these agents, water exercises the most constant and important influence. The fragments detached by the operation of atmospheric causes are carried, by means chiefly of rivers, down the mountainous and elevated districts, and ultimately deposited, together with the accumulated quantities gathered in the course of the descent, partly in the beds of the rivers themselves, but more extensively in the basins, lakes, seas, and oceans; to which they flow." Dr. Buckland also inferred the slow and gradual deposition of the stratified rocks, during long periods of time and at widely distant intervals, from the fact that a large proportion of the remains of animals and vegetables, from time to time discovered and brought to light by the researches of geologists, belong to extinct genera, and to species that lived and multiplied and died on or near the spots where they were found, and that they differ more and more widely from existing species as the strata in which they were found descends in depth.

"The changes that have taken place in the courses of rivers," says Professor Playfair, "are to be traced in many instances by successive platforms of flat alluvial lands, rising one above another, and marking the different levels on which the river has run at different periods of time. The channels of these rivers have evidently been cut by the waters themselves—slowly dug out by the washing

and erosion of the land; and it is by the repeated touches of the same instrument that this curious assemblage of lines has been engraved so deeply on the surface of the globe. In the same manner, when a river undermines its banks, it often discovers deposites of sand and gravel that have been made when it ran on a higher level than it does at present. In other instances the same strata are seen on both the banks, though the bed of the river is now sunk deep between them, and perhaps holds as winding a course through the solid rock as if it flowed along the surface: a proof that it must have begun to sink its bed when it ran through such loose materials as opposed but a very inconsiderable resistance to its stream. A river, of which the course is both serpentine and deeply-excavated in the rock, is among the phenomena by which the slow waste of the land, and also the cause of that waste, are most directly pointed out. It is, however, where rivers issue through narrow defiles among mountains, as in the case of the Potomac, where it penetrates the ridge of the Alleganies, that the identity of the strata on both sides is most easily recognised, and remarked, at the same time, with the greatest wonder. It is only the philosopher who has deeply meditated on the effects which action long continued is able to produce, and on the simplicity of the means which nature employs in all her operations, who sees in this nothing but the gradual working of a stream that once flowed on the top of the ridge which it now so deeply intersects, and has cut its course through the rock, in the same way and almost with the same instrument by which the lapidary divides a block of marble or granite."

"If the orologist," he continues, in another place, "would trace back the progress of waste, till he came in sight of that original structure of which the remains are still so vast, he perceives an immense mass of solid rock, naked and unshapely, as it first emerged from the deep,

and incomparably greater than all that is now before him. The operation of rains and torrents, modified by the hardness and tenacity of the rock, has worked the whole into its present form; has hollowed out the valleys and gradually detached the mountains from the general mass, cutting down their sides into steep precipices at one place, and smoothing them into gentle declivities at another. From this has resulted a transportation of materials, which, both for the quantity of the whole, and the magnitude of the individual fragments, must seem incredible to every one who has not learned to calculate the effects of continued action, and to reflect that length of time can convert accidental into steady causes. Hence fragments of rock from the central chain are found to have travelled into distant valleys, even where many inferior ridges intervene; hence the granite of Mont Blanc is seen in the plains of Lombardy, or on the sides of Jura, and the ruins of the Carpathian mountains lie scattered over the shores of the Baltic. Thus, with Dr. Hutton, we shall be disposed to consider those great chains of mountains which traverse the surface of the globe, as cut out of masses vastly greater and more lofty than anything that now remains.

"Such are the changes which the daily operations of waste have produced on the surface of the globe. These operations, inconsiderable if taken separately, become great by conspiring all to the same end—never counteracting one another, but proceeding through a period of indefinite extent, continually in the same direction. Thus, everything descends; nothing returns upward; the hard and solid bodies everywhere dissolve, and the loose and soft nowhere consolidate. The powers which tend to preserve, and those which tend to change the condition of the earth's surface, are never *in equilibrio;* the latter are in all cases the most powerful, and, in respect of the former, are like *living* in comparison of *dead* forces. Hence the law of

decay is one which suffers no exceptions. The elements of all bodies were once loose and unconnected, and to the same state nature has appointed that they should all return. It affords no presumption against the reality of this progress, that, in respect of man, it is too slow to be immediately perceived. The utmost portion of it to which our experience can extend, is evanescent, in comparison with the whole, and must be regarded as the momentary increment of a vast progression, circumscribed by no other limits than the duration of the world. Time performs the office of integrating the infinitesimal parts of which this progression is made up: it collects them into one sum, and produces from them an amount greater than any that can be assigned.

"While on the surface of the earth so much is everywhere going to decay, no new production of mineral substances is found in any region accessible to man. We are not, however, to imagine that there is nowhere any means of repairing this waste: from comparing the conclusion at which we are now arrived, viz., that the present continents are all going to decay, and their materials descending into the ocean, with the proposition first laid down, that these same continents are composed of materials which must have been collected from the decay of former rocks, it is impossible not to recognise two corresponding steps of the same progress—of a progress by which mineral substances are subjected to the same series of changes, and alternately wasted away and renovated. In the same manner as the present mineral substances derive their origin from substances similar to themselves, so from the land now going to decay—the sand and gravel forming on the seashore or on the beds of rivers; from the shells and corals which in such enormous quantities are every day accumulated in the bosom of the sea; from the drift-wood and the multitude of animal and vegetable remains con-

tinually deposited in the ocean: from all these, we can not doubt that strata are now forming in those regions to which nature seems to have confined the powers of mineral reproduction; from which, after being consolidated, they are again destined to emerge, and to exhibit a series of changes similar to the past. How often these vicissitudes of decay and renovation have been repeated, is not for us to determine: they constitute a series of which *we see* neither the beginning nor the end; a circumstance that accords well with what is known concerning other parts of the economy of the world. In the continuation of the different species of animals and vegetables that inhabit the earth, *we discern* neither a beginning nor an end; and in the planetary motions, where geometry has carried the eye so far, both into the future and the past, we discover no mark, either of the commencement or the termination of the present order. It is unreasonable, indeed, to suppose that such marks should anywhere exist. The Author of Nature has not given laws to the universe, which, like the institutions of men, carry in themselves the elements of their own destruction. He has not permitted in his works any symptoms of infancy or of old age, or any sign by which we may estimate either their future or their past duration. He may put an end, as he no doubt gave a beginning, to the present system, at some determinate period; but we may safely conclude that this great catastrophe will not be brought about by any of the laws now existing, and that it is not indicated by anything which we perceive. To assert, therefore, that in the economy of the world, *we see* no mark, either of a beginning or an end, is very different from affirming that the world *had* no beginning and will have no end. The first is a conclusion justified by common sense as well as sound philosophy; while the second is a presumptuous and unwarrantable assertion, for which no reason, from experience or analogy, can ever be assigned."

"It is impossible to look back on the system which we have thus endeavored to illustrate, without being struck with the novelty and beauty of the views which it sets before us. We have been long accustomed to admire that beautiful contrivance in nature by which the water of the ocean, drawn up in vapor by the atmosphere, imparts in its descent fertility to the earth, and becomes the great cause of vegetation and of life; but now we find that this vapor not only fertilizes, but creates the soil—prepares it from the solid rock, and after employing it in the great operations of the surface, carries it back into the regions where all its mineral characters are renewed. Thus the circulation of moisture through the air is a prime mover, not only in the annual succession of the seasons, but in the great geological cycle by which the waste and reproduction of entire continents is circumscribed. Perhaps a more striking view than this of the wisdom that presides over nature, was never presented by any philosophical system, nor a greater addition ever made to our knowledge of final causes. It is an addition which gives consistency to the rest, by proving that equal foresight is exerted in providing for the whole and for the parts, and that no less care is taken to maintain the constitution of the earth than to preserve the tribes of animals and vegetables which dwell on its surface. In a word, it is the peculiar excellence of this theory, that it ascribes to the phenomena of geology an order similar to that which exists in the provinces of nature with which we are best acquainted, that it produces seas and continents, not by accident, but by the operation of regular and uniform causes: that it makes the decay of one part subservient to the restoration of another, and gives stability to the whole, not by perpetuating individuals, but by reproducing them in succession."

"I question," observes Professor H. D. Rogers in an address delivered by him before the American Association

of Geologists, "if many minds, even among those devoted to geological researches, are impressed with the wonderful extent to which this science is likely in future ages to carry the restoration of antiquity, reproducing in vivid distinctness the ancient geography, climate, and inhabitants of the globe; tracing the many successive oceans, bays, and shores; and repeopling, for each epoch, all the waters and the land. I question if we are at all aware how completely the whole history of all departed time lies indelibly recorded, with the amplest minuteness of detail, in the successive sediments of the globe; how effectually, in other words, every period of time has *written its own history*, carefully preserving every created form, and every trace of action."

PART III.

SCIENTIFIC DIVISIONS OF GEOLOGY.

THE primary division of rocks, adopted by geologists, is into *igneous* and *aqueous*, *crystalline* and *sedimentary*, *unstratified* and *stratified*. All the igneous rocks are unstratified: but there are some rocks of undoubted igneous origin, which are not crystalline; and, on the other hand, there are limestones of aqueous origin, not only stratified but crystallized. Some of the lower stratified rocks are also of a decided crystalline character: but their origin is not clearly ascertained. On the one hand, they graduate into rocks which appear to have been formed by igneous action; and, on the other, into fragmentary rocks of aqueous origin. There are other rocks which exhibit a blending of the crystalline and mechanical structure. Rocks are also divided into *fossiliferous* and *non-fossiliferous*—those which, taken as a whole, contain organic remains, and those in which such remains rarely if ever occur. Of the latter class are the igneous and unstratified rocks—consisting of a few simple minerals, variously combined; occurring in irregular masses beneath the other strata; protruding through, or traversing them vertically, in dikes or veins; and bearing no constant relation to each other or to the stratified rocks.

Granite, upon which all the superimposed strata rest, has, according to the Huttonian theory, been formed, or at least fused and upheaved, *subsequently* to the deposition of the superincumbent rocks, and is entirely destitute of

organic remains. Intimately connected in composition with this class of rocks, and, like them, destitute of organic remains, is the lower series of the stratified rocks, termed, by Mr. Lyell, *metamorphic*. The remainder is a succession of clays, sandstone, and limestone, alternating in no fixed or definite order, as regards their mineral composition, but capable, nevertheless, of subdivision into groups, characterized over very extensive areas by peculiar assemblages of organic remains. Here, and in the diluvial deposites immediately above, are found the remains of the gigantic mammalia and other quadrupeds, erroneously supposed by some to have been destroyed by the action of the flood recorded in scripture. Upon the surface of the tertiary strata we have volcanic and basaltic rocks, and alluvial and diluvial soils, constituting the existing superficial surface of the globe. Within none of the strata formed anterior to the last general deluge have the bones, utensils, or other vestiges of man, as yet been discovered.

The ordinary materials of which the several strata are composed, are sand, clay, and carbonate of lime, giving rise to the division of rocks into *arenaceous, sandy* or *siliceous, argillaceous* and *calcareous* or limestone, consisting of carbonic acid and lime. These three classes of rock, however, pass continually into each other, and rarely occur in a perfectly separate and pure form. Magnesian limestone, or *dolomite*, and *gypsum*, or plaster of Paris, also occasionally occur.

The division of the *stratified* rocks most generally adopted by modern geologists, is into—1st. Primary; including the whole of the non-fossiliferous strata: 2d. Lower secondary; commencing with the oldest formation in which organic remains are found, and including, in the ascending order, the coal-bearing strata or carboniferous system: 3d. Upper secondary; commencing with the

new red sandstone, immediately above the coal, and terminating with the chalk: 4th. Tertiary; comprising all those regular deposites above the chalk, newer than the secondary formations, and originating prior to the appearance of man, in which existing species are found, mixed with others now extinct. This formation has been subdivided by Mr. Lyell, according to the proportion of shells of existing species contained in its strata into *eocene*, *miocene*, and *older and newer pliocene strata*: 5th. Modern or recent; consisting of *diluvial* and *alluvial* formations, containing human remains, or the remains of existing species of animals, unmixed with others that are extinct.

The following table exhibits a synoptical view of the succession of stratified rocks as found in Great Britain; their arrangement into the three classes of primary, secondary, and tertiary; the thickness of the respective systems; and their minor general subdivisions:—

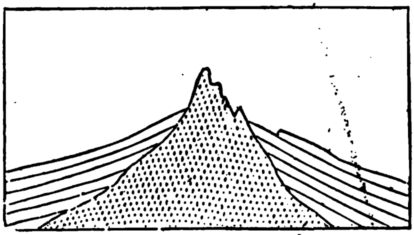
Modern Group—Lacustrine, Fluviatile, and Marine deposites, now in progress.
Erratic Block Group—Diluvium—Drift.

Strata.	Systems.	Feet.	Formations.
Tertiary.	Newer Pliocene. Older Pliocene. Miocene, Eocene,	 11 to 30 600 to 1,800	
Upper Secondary.	Cretaceous System,	600 500	Chalk Formation. Greensand, do.
	Oolitic System,	900 400 450 400 1,000	Wealden. Upper Oolite. Middle Oolite. Lower Oolite. Lias.
Lower Secondary.	Poikilitic System,	900 300	New Red Sandstone. Magnesian Limestone.
	Carboniferous System,*	3,000 2,400 300 to 10.000	Coal-Formation. Carboniferous Limestone. Old Red Sandstone.
	Silurian System,	7,500	Ludlow, Wenlock, Caradoc, and Llandeilo Formations.
	Cambrian System	10,000	Upper and Lower Cambrian.
Primary.	Mica Schist System.	Unknown.	Mica Schist.
	Gneiss System,	Unknown.	Gneiss.

* It has been proposed by Professor Sedgwick and Mr. Murchison, to include the old red sandstone and certain slate-rocks constituting a zoological passage from the Silurian to the carboniferous system, into a new group, under the name of the Devonian system ; and it is probable that some such arrangement may eventually be adopted.

The primary rocks consist of granite and other rocks of a much more compact and crystalline texture than the sedimentary or volcanic formations. In the unstratified portion of these crystalline masses, no organic fossil remains have ever been discovered. A considerable portion of these rocks are, however, divided into strata and

laminæ, so closely imitating those of aqueous deposites as, in the opinion of Mr. Lyell and other able geologists, to leave scarcely any reasonable doubt that they owe this part of their texture to similar causes. "These remarkable formations," says Mr. Lyell, "have been called primitive, from their having been supposed to constitute the most ancient mineral productions of the globe, and from a notion that they originated before the earth was inhabited by living beings, and while yet the planet was in a nascent state. The high relative antiquity of some of them is indisputable: for in the oldest sedimentary strata containing organic remains, we often meet with rounded pebbles of the crystalline rocks, which must, therefore, have been consolidated before the derivative strata were formed out of their ruins. The members of this granitic group generally rise up from beneath the rocks of mechanical origin, entering into the structure of lofty mountains, so as to occupy, at the same time, the lowest and most elevated positions in the crust of the globe."



Nothing strictly analogous to these crystalline formations can now be seen in the progress of formation on the habitable surface of the earth, within the range of human observation. The earlier speculators in geology explained their origin on the supposition of a former condition of

the planet different from the present, when certain chymical processes were developed on a great scale, forming crystalline precipitates, some more suddenly and in huge amorphous masses, such as granite; others, by successive deposition and with a foliated and stratified structure, as in the rocks termed gneiss and mica-slate. It is needless to observe, that a great part of these views have since been abandoned; especially in reference to the origin of granite, which is now almost universally believed to be the result of igneous fusion.

The primary stratified rocks all repose upon an uneven irregular granite surface, which, in some instances attains the height of more than five miles above the level of the sea, and in others is depressed to an unknown depth below the bed of the ocean. On this base, the earliest stratified rocks have been formed: they do not, however, cover its whole surface; the granite rocks frequently rising in bold outline above all the stratified rocks, and forming the peaks of the highest mountains.

"It is a fact established on good evidence," says a late writer in the Edinburgh Review, "that igneous matter has, during many periods, been protruded from below; that mountains have risen in succession from the sea; and injected their molten substance through the cracks and open fissures of the superincumbent strata. Many masses of granite and other forms of igneous rock became the solid bottom of some portions of the sea before the secondary strata were laid gradually upon them. The granite of Mont Blanc rose during a recent tertiary period. We can prove more than mere shifting of level, and that many portions of sea and land have entirely changed their places. The rocks at the top of Snowdon are full of petrified sea-shells; the same may be said of some high crests of the Alps, Pyrenees, and Andes. We have proof demonstrative that many parts

of Scotland, and that all England, formed, during many ages, the solid bottom of the old sea. It may be true that the antagonist powers of nature, during the human period, have reached a kind of balance. But during all geological periods, there have been such long intervals of repose, or of such gradual movements, that we can trace the history of the earth in the sucessive deposites formed in the waters of the sea. This is the great business of geology."

The rocks commonly designated *transition rocks*, corresponding in the main to the lower secondary strata of modern geologists, are composed of alternating strata of conglomerates and sandstones, limestones, slate, and shell; the former exhibiting traces of violent aqueous action, and the other containing animal and vegetable fossils. Of the latter, those which occur in the lower beds, are few in number, and principally of marine origin; while the upper compose the great coal formation, consisting of prodigious accumulations of the vegetable remains of the earliest periods of our globe. To Professor Sedgwick and Mr. Murchison, geology is indebted for the classification of these rocks into systems and formations defined by peculiar lithological and zoological characters. Organic remains have been discovered in them in various parts of central and northern Europe; "and they appear," says Mr. Lyell, "to have been deposited in a sea of considerable extent. The fossils have been regarded by many naturalists as indicating a greater uniformity in the species of marine animals inhabiting the sea at that early period than would now be found to prevail in a similar extent of ocean." Hitherto but few vegetable remains have been noticed; but such as are mentioned are said to agree more nearly with the plants of the carboniferous era than any other, and would, therefore, imply a tropical and humid atmosphere.

The *transition* period has been divided by most European geologists into two groups, the Cambrian and Silurian—chiefly distinguished from the slaty formations of the primary period by the traces of organic remains, and consequently appearing to occupy an intermediate position between the primary stratified rocks and those of the secondary period. Igneous rocks are found associated with those of this period, and particularly with those of the Silurian system: in some instances piercing the superincumbent sandstone; in others, extended in the form of layers between the strata; and in others still, converted by the agency of water into rocks, to which the name of volcanic sandstone has been applied. Veins of lead ore are of frequent occurrence in this system, especially when in conjunction with the igneous rocks. The organic remains, although numerous and extensive, differ from any existing species. Many of the limestones of this period are supposed to consist of ancient coral-reefs, originally formed by the secretion of carbonate of lime by the polypi of the ancient ocean, and subsequently hardened and converted into the habitation of these animals. Encrinites also occur in this formation; and fragments of the stems or columns of these remarkable animals are abundant.

The *secondary strata* consist of extensive beds of sand and sandstone, interspersed occasionally with pebbles, and alternating with deposites of clay, marl, and limestone, derived from the detritus of primary and transition rocks. These, together with the tertiary formations, and the diluvial and alluvial deposites of a more recent period, compose that portion of the earth's surface destined for the habitation of man. The movements of the waters, by which their materials have been transported to their present place, have caused such an intermixture as essentially to promote the growth of the different vegetable productions required for the sustenance of man and beast. They

present unequivocal proofs of a mechanical and aqueous origin. In their arrangement in horizontal beds; in the subdivision of these beds into their layers, indicating successive deposites; and, in the shells which they contain, we have exact counterparts of those beds of sand and silt, now forming at the mouths of rivers, and in lakes and inland seas. The primary strata possess the same character of division into thick beds, and of subdivision into laminæ; but they contain no organic remains, and are of a crystalline structure, now generally believed to have been the result of the contact, at great depths from the surface, of vast masses of fused rock, intensely heated during the lapse of a series of ages, with sedimentary formations previously existing. According to these views, the primary strata may have assumed their crystalline structure at as many successive periods as there have been distinct eras of the formation of granite; and their difference of mineral composition may be attributed, not to an original difference of the conditions under which they were deposited at the surface, but to subsequent modifications superinduced by heat and other causes, at great depths below the surface.

"From the commencement of the fossiliferous series," observes Mr. Trimmer, "up to and including the period of the deposition of the new red sandstone, the next in the ascending series to the carboniferous, and comparatively destitute of organic remains, four distinct epochs are clearly defined—two of repose, and two of disturbance. During each period of repose, a great succession of aqueous deposites appear to have been formed, regularly and tranquilly, subject during their deposition to occasional local outbursts of igneous matter, like those of modern volcanic action, but not to any general fracture and elevation of the sedimentary state evinced by the discordant position of different members of the series. The first tranquil epoch comprises the Cambrian and Silurian systems; the second all the carbon-

iferous deposites. These two periods of repose were succeeded by two of the most general disruption of the earth's crust of which we have any evidence: being observable in so many and such widely distant localities, that they may almost be considered universal. Each of them is followed by the deposition of a series of elementary rocks *unconformable* to the strata below, among which organic remains and calcareous strata are rare. The prevalence of conglomerates, immediately succeeding each fracture and elevation of the strata, indicates powerful currents produced in the sea by the new condition of its bed. Their great mass is also indicative of the violence of the watery action, and the extensive degradation of the newly-raised land. The prevalence of sandstones and marl in the upper part of the red system shows a gradual diminution of the disturbing action, and a return from a very general state of disturbance to a very general state of repose—marked, however, by the extinction of large races of organic bodies."

The rocks of the *Cambrian* group afford the first undoubted traces of organic remains. They occur at but few points and in small quantities, amid a great thickness of sedimentary rocks, extending over a wide area; and this circumstance, connected with the paucity of species where the fossils are in the greatest abundance, appears favorable to the presumption that the absence of organic remains from the older stratified rocks is not the effect of any process by which they have been destroyed, and that in the Cambrian rocks we behold the first appearance of organic life. The fossils of the *Silurian* strata appear to be distinguished from them, not so much by change of type, as by the greater developments, both as to species and individuals, of already-existing forms. The rocks of the two systems may therefore be regarded as having been formed under nearly similar conditions. From the abundance of

porphyry and greenstone alternating with and passing into the sedimentary deposites, volcanic ejections appear to have been of frequent occurrence during this era, spreading sheets of lava over the floor of the ocean.

The term "*Devonian* system" has been proposed by Professor Sedgwick and Mr. Murchisón, to express all the intermediate deposites between the Silurian and carboniferous systems. These deposites are perhaps more generally known as those of the "old red sandstone formation."

On the old red sandstone usually rests the *carboniferous* limestone—a mass of rock composed of shells of several kinds, chiefly encrinites and corals, quietly deposited and cemented by a calcareous, semi-crystalline paste. The *carboniferous system* is of great thickness, extending in its fullest development to about five thousand feet, exclusive of the old red sandstone, and exhibiting throughout the strongest proofs of slow and successive deposites, in the abundance and perfect condition of its fossils—in the repeated alternations of strata, of different mineral composition—and in the laminated structure of its component members. The *coal formation* constitutes the upper part of this system. Its rocks are extremely rich in organic remains. The plants which occur chiefly in the coal formation are almost exclusively terrestrial, and are interstratified with deposites containing marine exuviæ—the results, probably, of the waste of ancient forests, annually carried down by great rivers to the sea, and of subsequent elevations and disturbances of the bed of the latter. The aquatic character of some of the plants indicates that they grew in freshwater lakes; and this conclusion is strengthened by the trunks of trees and other terrestrial vegetables, implying the existence of dry land, and the formation of these lakes in its vicinity. In the strata immediately succeeding the coal, the organic remains are of a marine nature, from which, and from their continuity over large areas, we in-

fer that subsequently to the formation of the coal, a considerable extent of the land was covered by the sea to a great depth. The same group is traceable, according to Mr. Lyell, not only through different parts of Europe, but also in North America, and toward the borders of the Arctic ocean. Igneous rocks are extensively associated with the deposites of this series as well in overlying masses, in stratiform beds, alternating with the sedimentary strata, as in dikes which have pierced through them.

"A wide expanse of ocean interspersed with islands," says Mr. Lyell, "seems to have pervaded the northern hemisphere at the periods when the transition and carboniferous rocks were formed, and the temperature was then hottest and most uniform. Subsequent modifications in climate accompanied the deposition of the secondary formations, when repeated changes were effected in the physical geography of our northern latitudes. Lastly, the refrigeration became most decided and the climate most nearly assimilated to that now enjoyed, when the lands in Europe and northern Asia had attained their full extension, and the mountain-chains their actual height."

"Coal," observes the author of "Recreations in Geology," "evidently owes its origin to accumulated masses of vegetables, altered and modified by being pressed beneath the weight of a thick deposite of mineral substances, and then exposed to a high temperature. If examined with a powerful microscope, coal presents a vegetable texture, and numerous remains of plants occur in the rocks which accompany it. The quality of the coal appears to depend partly on the nature of the plants of which it was originally composed, and partly on subsequent changes produced by subterranean movements and other causes." It has been made a subject of considerable discussion whether the plants from which coal originated, and of which it is composed, grew in the localities where the carbonifer-

ous deposites or coal measures have been formed, or were transported thither by drifts or currents. "Though it is by no means improbable," continues the author above quoted, "that some of these accumulations may have been formed, or perhaps increased, by drift-wood, the balance of evidence appears in favor of the opinion that the vegetable matter grew on the localities in which the coal is now found; and it is supposed that the surface of the earth at that period presented a series of swampy islands, and that on these islands grew a luxuriant vegetation, consisting of ferns, calamites, coniferous trees, &c., which, decaying and regenerating, accumulated in the same manner as peat-bogs. It is further supposed that the islands, by the subsiding or sinking of the agitated crust of the earth, were depressed beneath the surface of the sea, and covered over with drifted sand, clay, and shells, until they were, by this accumulation, again converted into dry land and clothed with another vegetation: an operation, it has been observed, which may have been repeated as many times in each coal-district as there are alternating layers of coal and of shale, or of other sedimentary strata."

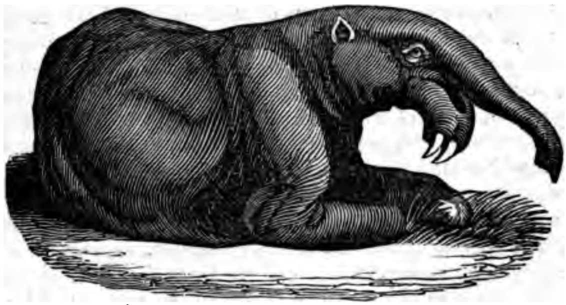
The luxuriant forests to which coal owes its origin seem to have been composed in a great measure of plants, of which the ferns, mosses, &c., of the present period are the representatives: neither the stems nor the leaves of these ancient vegetables bearing any resemblance to the trees of the present day. About four hundred species of arborescent or tree-ferns, and other plants belonging to the coal formation, have been described—some of them attaining to the height of seventy or eighty feet.

Notwithstanding the conceded possibility that a portion of the coal-beds, with their sandy and shaly accompaniments, have been the result of transportation, the most eminent modern geologists are understood to agree in the conviction that the great mass of these formations have

been derived "from trees of vast size and close contiguity, submerged in their native seats, without being removed from their place of growth, and marking their scarcely-disturbed prostration by the well-known impressions on the shale roofs and bottoms of their most delicate parts, which would have been greatly defaced, or quite obliterated, by even a little tossing and drifting. Detached pieces of trunks do indeed occur, whose denuded and broken state suggests a derivation from neighboring high land, and whose forms and positions prove them to have been accidental intruders: but the idea of masses of such vegetation as compose the coal-beds having floated from different quarters, and then, which must have been of necessity, irregularly and confusedly heaped together, appears to be absolutely irreconcilable with the facts exhibited in the impressions of the plants upon the shale, which has just been mentioned."

The character of the fossil vegetation of the earlier epochs is such as to warrant the conclusion that the plants of that epoch grew under a climate both hotter and moister than that of any part of the earth at present; and since, even in arctic regions, the fossil plants are found to be analogous to those now growing under the tropics, it seems probable that light as well as heat was more equally diffused. A great ocean, like the Pacific, interspersed with islands, appears to have prevailed during the deposition of the older strata, over that part of the northern hemisphere in which are situated those countries whose geology has been most thoroughly and systematically explored. The absence of the remains both of marine and terrestrial *mammalia* seems to indicate that this order of animals was not created until an epoch comparatively recent. The remains of land quadrupeds, imbedded in the older tertiary strata, are exclusively those of extinct genera; while in the deposites of a more recent period, we meet in northern latitudes with

the remains of extinct species of genera now existing, but existing only in warm climates, such as the elephant, hippopotamus, dinotherium, rhinoceros, &c. These are found



gradually intermixed in the ascending order of the strata, with the bones of mammalia, identical in species with those now living under the existing climates of the temperate zone; until at length we reach the alluvial deposites, in which human remains occur, mixed with those of existing species of animals. The surprising grandeur and luxuriance which characterized the vegetation of the *carboniferous* or *coal-bearing* strata, were doubtless the result of the more general and copious diffusion of heat and moisture, the two fundamental conditions of vegetable life. The extensive continents, now elevated above the sea, were then but inconsiderable islands. The ocean, from its immense surface, and its greater intrinsic warmth, yielded a greater quantity of evaporation. The presence, in large quantities, of carbonic acid gas—an element constituting an important portion of the nourishment of plants—also exerted a prominent influence in the production of this luxuriant vegetation, destined to supply to succeeding ages an inexhaustible store of materials for fuel.

"That the ancient seams of coal," observes Mr. Lyell, in his "Journal of a Tour in North America," "were produced for the most part by terrestrial plants of all sizes, not drifted, but growing on the spot, is a theory more and more generally adopted in modern times; and the growth of what is called sponge in such a swamp and in such a climate as the Great Dismal (in Virginia), already covering so many square miles of a low, level region bordering on the sea, and capable of spreading itself indefinitely over the adjacent country, helps us greatly to conceive the manner in which the coal of the ancient carboniferous rocks may have been formed. The heat perhaps may not have been excessive when the coal measures originated, but the entire absence of frost, with a warm and damp atmosphere, may have enabled tropical forms to flourish in latitudes far distant from the line. Huge swamps in a rainy climate, standing above the level of the surrounding firm land, and supporting a dense forest, may have spread far and wide, invading the plains, like some European peat-mosses when they burst; and the frequent submergence of these masses of vegetable matter beneath seas or estuaries, as often as the land sunk down during subterranean movements, may have given rise to the deposition of strata of mud, sand, or limestone, immediately above the vegetable matter. The conversion of successive surfaces into dry land, where other swamps supporting trees may have formed, might give origin to a continued series of coal measures of great thickness. In some kinds of coal the vegetable texture is apparent throughout, under the microscope; in others it has only partially disappeared; but even in this coal the flattened trunks of trees of the genera lepidodendron, sigillaria, and others, converted into pure coal, are occasionally met with, and erect fossil trees are observed in the overlying strata, terminating downward in seams of coal."

"It appears, from the researches of Liebig and other

eminent chymists, that when wood and vegetable matter are buried in the earth, exposed to moisture, and partially or entirely excluded from the air, they decompose slowly, and evolve carbonic acid gas—thus parting with a portion of their original oxygen. By this means, they become gradually converted into lignite, or wood-coal, which contains a larger proportion of hydrogen than wood does. A continuance of decomposition changes this lignite into common or bituminous coal, chiefly by the discharge of carburetted hydrogen, or the gas by which we illumine our streets and houses. According to Bischoff, the inflammable gases which are always escaping from mineral coal, and are so often the cause of fatal accidents in mines, always contain carbonic acid, carburetted hydrogen, nitrogen, and olefiant gas. The disengagement of all these gradually transforms ordinary or bituminous coal into anthracite," &c.

"Some imagine the air to have been so full of choke-damp during the ancient era alluded to, that it was unfitted for the respiration of warm-blooded quadrupeds and birds, or even reptiles, which require a more rapid oxygenation of their blood than creatures lower in the scale of organization, such as have alone been met with hitherto in the carboniferous and older strata. It is assumed that an excess of oxygen was set free, when the plants which elaborated the coal subtracted many hundred million tons of carbon from the carbonic acid gas which previously loaded the air. All this carbon was then permanently locked up in solid seams of coal, and the chymical composition of the earth's atmosphere essentially altered. But they who reason thus are bound to inform us what may have been the duration of the period in the course of which so much carbon was secreted by the powers of vegetable life; and, secondly, what accession of fresh carbonic acid did the air receive in the same. We know that in the

present state of the globe, the air is continually supplied with carbonic acid from several sources, of which the three principal are—first, the daily putrefaction of dead animal and vegetable substances; secondly, the disintegration of rocks charged with carbonic acid and organic matter; and thirdly, the copious evolution of this gas from mineral springs and the earth, especially in volcanic countries. By that law which causes two gases of different specific gravity, when brought into contact, to become uniformly diffused and mutually absorbed, through the whole space which they occupy, the heavy carbonic acid finds its way upward through all parts of the atmosphere, and the solid materials of large forests are given out from the earth in an invisible form, or in bubbles rising through the water of springs. Peat-mosses of no slight depth, and covering thousands of square miles, are thus fed with their mineral constituents, without materially deranging the constituents of the atmosphere breathed by man. Thousands of trees grow up, float down to the delta of the Mississippi and other rivers, and are buried; and yet the air, at the end of many centuries, may be as much impregnated with carbonic acid as before. Coral-reefs are, year after year, growing in the ocean—springs and rivers feed the same ocean with carbonic acid and lime; but we have no reason to infer that when mountain-masses of calcareous rock have thus been gradually formed in the sea, any essential change in the chymical composition of its water has been brought about. We have no accurate data as yet for measuring, whether, in our own time, or at any remote geological era, the relative supply and consumption of carbon in the air or the ocean, causes the amount of those elements to vary greatly; but the variation, if admitted, would not have caused an excess, but rather a deficit of carbon in the periods most productive of coal or peat, as compared to any subsequent or antecedent epochs. In fact, a climate

favoring the rank and luxuriant growth of plants, and at the same time checking their decay, and giving rise to peat, or accumulations of vegetable matter, might, for the time, diminish the average amount of carbonic acid in the atmosphere—a state of things precisely the reverse of that assumed by those to whose views I am now objecting."

Iron ore is frequently found in the vicinity of the coal-beds, accompanied in some instances by limestone and other stone adapted to the construction of furnaces, &c. It is also occasionally met with in the form of iron pyrites, possessing a metallic lustre.

After the deposition of the carboniferous system, and prior to that of the overlying rocks, very extensive disturbances and dislocations appear, as has already been stated, to have taken place. In the British islands, the various coal-districts were universally disturbed and shaken, and faults or dikes are found passing in every direction. In some instances the dislocations appear to have been accompanied with a violence sufficient to produce the actual overthrow of the strata.

The *Poikilitic* (variegated) or *new red sandstone system* comprises a mass of arenaceous and argillaceous deposites immediately above the coal formation, the characteristic color of which is red, or red variegated with blue and other colors, yielding gypsum, magnesia, and rock-salt, in abundance, but extremely poor in organic remains.

The *Oolitic* group, the next in the ascending series above the new red sandstone, is extremely rich in organic remains, chiefly marine, and entirely distinct from those of the system above and below it. These remains appear to have been suddenly enveloped in sediment, if, as Mr. Dela-Beche has observed, they were not actually buried alive.

The *cretaceous system* is the highest member of the secondary formations, and consists of the green sand and chalk deposites. The organic remains are chiefly of ma-

rine origin, and afford a group entirely distinct from those of the oolitic rocks below, and the members of the tertiary strata above. Neither land nor fresh-water shells, nor bones of mammalia, have been met with in this system.

With the chalk terminates the long series of the secondary strata, in which all the species and many of the genera of organic bodies are distinct from those now living. The peculiar feature of the secondary strata seems to be the prevalence of numerous and gigantic forms of saurian reptiles—marine, amphibious, and terrestrial.

Between the uppermost member of the secondary series, and the lowest of the tertiary, Mr. Lyell remarks a singular discordance as to *species* of organic remains, none having, as yet, been discovered common to both. "This abrupt transition from one set of fossils to another," he observes, "is also accompanied by evident signs of a *change of climate;* the older tertiary species having a far less tropical aspect than those found fossil in the newest secondary group." The prevalence and general diffusion, during those early periods when the lower secondary strata were in process of formation, of a high temperature, indicated by the tropical luxuriance of the vegetation from which the immense series of the coal formations originated, are also attributed by this eminent geologist to the great preponderance of water over the land. This hypothesis, it must be admitted, is strongly countenanced by the existing economy of nature, and by the gradual reduction of temperature consequent upon a different distribution of land and water.

The greater part of the *tertiary* strata consists of unconsolidated beds, resembling deposites now in the course of formation; and in these the shells are filled with loose sand or clay, and have merely parted with some of their animal matter; in some cases even retaining their color. The tertiary strata are distinguished from the secondary

by the circumstances under which they appear to have been formed. From the occurrence of the secondary strata in large sheets of rock continuous over extensive areas, it would appear that, during their deposition, a great ocean must have prevailed over most of the northern hemisphere. The tertiary strata, however, were formed after the elevation of large portions of land; and the division of the European seas into groups, bays, and estuaries of limited extent, but great depth; and occasionally alternations of marine and fluviatile deposites show that during this period the land was repeatedly elevated and submerged; that large inland lakes were numerous, and large rivers constantly emptying themselves into gulfs of the sea. No species of fossils identical with those of the underlying secondary strata, have been discovered in these formations in Europe; and they alone are found to contain fossil specimens of existing species; more numerous in proportion as the strata are more recent.

Numerous deposites, containing exclusively terrestrial remains and fresh-water shells and fishes prove that the continents and large islands of the tertiary epoch were extensively covered by lakes. The strata of the eocene epoch were the first tertiary deposites that attracted the attention of geologists. The mammalian remains of the miocene and pliocene epochs, are found drifted into seas and estuaries, accompanied by marine shells, and in the neighborhood of contemporary accumulations on the surface of the land; in lacustrine and fluviatile deposites, mixed with land and fresh water shells; in caverns, such as the Kirkdale cave, in Yorkshire, which appears to have been long the abode of hyenas, by whom the remains of various animals were dragged in for food; in fissures, connected with caves; and in accumulations of alluvial gravel covered by lava. They also occur mixed with marine shells of existing species, and with large boulders and

smaller detritus transported from a great distance, by extraordinary marine currents. This *erratic block group*, as it is termed, separates the tertiary series from the *modern group*, comprising all those formations now completed, or in progress, on the surface of the earth, or in its waters, which contain the remains of man and his works, or the remains of plants and animals of existing species.

The tertiary epoch exhibits the closest analogy to the existing appearance of things. During the passage from this epoch to the modern period, marine currents of extraordinary violence appear to have dispersed large boulders from the north over the more central and southerly regions of Europe and North America; and this state of things to have been succeeded by strata, containing the remains of man and of contemporaneous animals. As yet, no human remains have been found in or below the diluvial deposites, nor in any part of the tertiary strata; but no evidence at present exists to enable us to determine whether the most recent of these diluvial deposites preceded or followed the creation of man.

Previous to the last diluvium of the tertiary series, there appears to have been a series of cataclysms in almost every part of the earth, submerging many species of animals and vegetables, extinguishing their races, and leaving that deposite to which the name *diluvium* has been given; deluges attended with more or less marks of great violence in every country subjected to their action.

All the strata, subsequent to the primary, with the exception of the volcanic, seem to have been the deposited *debris* of the rocks, disintegrated and suspended during the particular convulsion that gave birth to the stratum; every stratum differing in mineralogical composition, and in the organic remains imbedded in it from that below and that above it; and whenever the imbedded fossils are

the same, in the same stratum in different regions and countries, the strata so containing similar characterizing fossils, have been deposited in conformity to the same law, *and at one and the same geological period of time;* and this, even though the mineralogical character of the stratum should not be, as it, however, generally is, similar in each region.

Each formation or group of strata is found to be the peculiar receptacle of certain specific minerals. Tin is found in granitic districts only. Copper is most abundant in those and the adjoining rocks. Lead, silver, and some other metals exist in the carboniferous formation, upon which the great body of the coal measures rests, and are found in veins traversing the strata. Gold, although rarely occurring in veins, is disseminated in small quantities through the rocks in which it exists, and the principal supplies of it, as well as of platinum and diamonds, are derived from alluvial gravel, resulting from the destruction of those rocks. Iron occurs in the greatest abundance, interstratified with coal. Copper is not generally met with in series more recent than the old red sandstone. Coal is now almost universally regarded as vegetable matter accumulated during the earlier ages of the world, the wreck of primeval forests that flourished long anterior to the existence of the human race.

The primitive strata contain sand, gravel, and other materials, collected, as already shown, from the dissolution of mineral bodies which must have had an existence long prior to the formation of the most ancient of the present continents. "In this gravel," says Playfair, "we sometimes find pieces of sandstone and of other compound rocks by which we are, of course, carried back a step further, so as to reach a system of things, from which the present is *the third in succession,* and the most ancient

of which any memorial exists in the records of the fossil kingdoms.

"Next in the order of time to the consolidation of the primary strata, we must place their elevation; when from being horizontal, and at the bottom of the sea, they were broken, set on edge, and raised to the surface. It is even probable that to this succeeded a depression of the same strata, and a second elevation, so that they have *twice* visited the superior, and twice the inferior regions; and next were deposited the strata termed secondary.

"The third great event was the raising up of this compound body of old and new strata from the bottom of the sea, and forming it into the dry land, or the continents as they now exist. Contemporary with this, we must suppose the injection of melted matter among the strata, and the consequent formation of the crystallized and unstratified rocks; the granite, metallic veins, and veins of porphyry, and trapstone. This, however, is to be considered as embracing a period of great duration.

"In the fourth place, with respect to time, we must class the facts that regard the detritus and waste of the land; the shaping of the existing inequalities of the surface; the formation of hills of gravel, and of the strata called *tertiary*, consisting of loose and unconsolidated materials; collections of shells and petrifactions; and lastly, the bones of land animals found in the soil."

That the condition of the earth's surface has undergone a series of changes by submersion under oceanic or fresh water, and frequent elevation; and that each of those successive states continued many thousands of years, has been demonstrated beyond the possibility of doubt. Throughout all that portion of the earth's crust now elevated above the water, until we arrive, in the descending order, to the earliest strata, geologists have found unquestionable traces of the remains of animals, disposed

in what must, originally, have been a horizontal order, and spread over large surfaces—often of the same species, or family—in all stages of their growth, and retaining their distinctive characteristics and forms. In some portions of the secondary strata, the skeletons of gigantic animals of the lizard tribe are found, the stomachs of which contain the scales and bones of fishes. Each successive deposite or formation seems to be furnished with its own peculiar animal and vegetable remains, the differing natures of which indicate great and progressive alterations in temperature and other circumstances connected with their existence.

"Geology points," observes Mr. Trimmer, in his "Elements," "to a bed of rock, a few feet in thickness, teeming with the remains of organic life: and from the successive generation of individuals which it contains, and from other indications, proves that a very long period must have been required for its formation. She then conducts us through a vast series of similar submarine deposites, five or six miles in depth, abounding with the remains of plants and animals, and containing not only the relics of successive generations of individuals, but of successively-created races, each group of strata having its peculiar group of organic remains; and finally leads us to those formations now in progress, in which he and his works are imbedded, together with the remains of the contemporary species of plants and animals. Man is found to be but a creature of yesterday, compared with the globe he inhabits, and with the other beings with which it has been peopled. The very species of plants and animals now existing are found to have been called into being before him, for their remains occur in older and deeper strata. The remains of existing species are gradually intermixed with those of species that have vanished from the face of the earth. The proportion of extinct species increases as we descend.

We come to lower beds still, in which not only extinct *species* occur, but extinct *genera*. The forms of organic life recede more and more from existing types, till at last we lose all traces of them. During our progress through this vast series of rocks, evidently of submarine formation, we meet with others bursting through them, which are clearly of igneous origin and derived from below. The lowest rocks we meet with are of this igneous character, and contain no organic remains. It may be that we have reached the records of a period when the world was unfit for the support of animal and vegetable life. It may be that the rocks in question once contained the remains of earlier races, but that all traces of them have been obliterated by the fusion to which the rocks have been exposed."—"The paucity of remains," remarks the same author in another place, "in the earlier fossiliferous strata, appears to favor the conclusion that the still older stratified rocks which contain no organic remains were deposited when the ocean was destitute of living beings. It is, however, certain that we repeatedly see the commencement of new races. If we examine the marine remains of the strata, we find that the whole genera of shells now abundant in species in the existing seas, were not in being till after the deposition of the *chalk* formation. Other genera originated about the middle of the series, and soon became extinct, being represented by no species in the *tertiary* strata immediately succeeding the chalk. Some genera are peculiar to the lower group of rocks—not a single species of them occurring higher in the series than the coal measures. A few, and but a few, *genera*, commencing in the lowest fossiliferous strata, have *species* existing in the present seas."

The formations containing *vegetable remains* may be arranged, according to Professor Henslow, in four groups, representing epochs, during any one of which no marked

difference is observable in the general character of the vegetation; but between any two of these groups the change is striking and decided—most of the genera and all the species being different.

"As by studying the external configuration of the existing land and its inhabitants," says Mr. Lyell in his "Principles of Geology," "we may restore, in imagination, the appearance of the ancient continents which have passed away, so may we obtain from the deposites of ancient seas and lakes an insight into the nature of the sub-aqueous processes now in operation, and of many forms of organic life, which, though now existing, are veiled from sight. Rocks, also, produced by subterranean fire in former ages, at great depths in the bowels of the earth, present us, when upraised by gradual movements, and exposed to the light of heaven, with an image of those changes which the deep-seated volcano may now occasion in the nether regions. Thus, although we are mere sojourners on the surface of the planet, chained to a mere point in space, enduring but for a moment of time, the human mind is not only enabled to number worlds beyond the unassisted ken of mortal eye, but to trace the events of indefinite ages before the creation of our race, and is not even withheld from penetrating into the dark secrets of the ocean, or the interior of the solid globe; free like the spirit which the poet described as animating the universe:—

> ——————" ire per omnes
> Terrasque, tractusque maris, cœlumque profundum."

The attention of geologists was at an early period directed to a variety of phenomena indicating the passage of large bodies of water at a recent epoch over a great part of the northern hemisphere. These evidences of diluvial action consisted of gravel composed chiefly of frag-

ments of rocks in various states of attrition, mixed with huge blocks of granite and other rocks which must have been drifted from a distance, and have frequently been found lodged high on the flanks of mountains, between which and the chain whence they were derived, wide and deep valleys are found to intervene. Bones of mammiferous quadrupeds, of existing genera, but extinct species, or of species existing at present only in warm climates, have been discovered in this drifted matter, mixed with those of existing species, and more recently with fragments of marine shells of existing species, sometimes at considerable height. These vast masses of diluvial gravel have been very generally attributed by geologists to violent irruptions of water, the effects of a general deluge, or the impetuous action of glaciers, proceeding from the highest mountains of the north.

The erratic-block period is supposed, by Professor Agassiz, Dr. Buckland, and Mr. Lyell, to have been a period of intense cold intervening between the present era and that during which the large mammalia existed, whose remains are buried in and beneath the deposites hitherto regarded as diluvial. It is supposed by these authors that during this glacial period the temperate regions of Europe and all countries where unstratified gravel is found, were overspread with glaciers and sheets of ice, like those now existing in Greenland; that the unstratified boulder-clay was produced by the trituration of ice upon the surface of the rocks; that the rounded, polished, and *striated* condition of that surface was caused by the descent of the glaciers; that the angular blocks occurring on the surface of the rounded materials were deposited in their present position by the melting of the ice; and that the disappearance of large bodies of ice produced enormous debacles, and considerable currents, by which erratic blocks were conveyed on masses of ice in diverging directions.

"For the moving of large masses of rocks," observes Professor Playfair, "the most powerful agents, without doubt, which nature employs, are the *glaciers*—those lakes or rivers of ice which are formed in the highest valleys of the Alps and other mountains of the first order. These great masses are in perpetual motion, undermined from the influx of heat from the earth, and impelled down the declivities on which they rest by their own enormous weight, together with that of the innumerable fragments of rock with which they are loaded. These fragments they gradually transport to their utmost boundaries, where a formidable wall ascertains the magnitude and attests the force of the great engine by which it was erected. The immense quantity and size of the rocks thus transported have been remarked with astonishment by every observer, and explain sufficiently how fragments of rocks may be put in motion, even where there is but little declivity, and where the actual surface of the ground is considerably uneven. In this manner, before the valleys were cut out in the form they now are, and where the mountains were still more elevated, huge fragments of rock may have been carried to a great distance: and it is not wonderful if these same masses, greatly diminished in size, and reduced to gravel and sand, have reached the shores, or even the bottom of the sea. Next in force to the glaciers, the torrents are the most powerful instruments employed in the transportation of stones," &c. M. Venetz, an intelligent engineer of the canton of Valais, in Switzerland, was the first to maintain, as early as 1821, the modern hypothesis of the former great extension of these glaciers as the transporting agents of erratic blocks. M. de Charpentier, an eminent mineralogist and geologist, became a convert to this doctrine in 1834; and in 1836 Professor Agassiz adopted the theory, and, in a very able work devoted to its consideration, seems disposed to admit the probability of a

former great envelope of ice in the extra-tropical regions of the globe. These theories are still undergoing examination and discussion in Europe and America; and however strongly supported, can not yet be regarded as fully established.

PART IV.

GEOLOGICAL FEATURES OF THE UNITED STATES, AND OF THE STATE OF NEW YORK.

THE primary rocks of the American continent, stratified and unstratified, are found generally to correspond in structure and appearance with those of the eastern world, and are consequently easily identified with them. The vast basin of the Mississippi is mostly bounded on three sides by these rocks, while the secondary and tertiary strata are found chiefly in that valley and on the Atlantic slope, covering an extent of area unequalled in any other part of the world. That portion of the fossiliferous rocks usually denominated transition or lower secondary, is immensely developed, especially in the northern and eastern states, part of New York, and in those states through which the longitudinal divisions of the great Appalachian chain of mountains extends. The Silurian formation presents extensive and strongly-marked features in western New York and in the western states generally. Particular formations are found associated, and running longitudinally, northerly, and southerly, through the entire continent—comprising the best and most valuable architectural materials, and the most useful minerals. Ores of iron, tin, copper, lead, and even gold and silver, abound ; and coal-fields of unequalled magnitude and richness, together with soils of every variety, furnish our rapidly-increasing population with all the means and resources of individual prosperity and national wealth. Over vast regions there are no indications

of violent disturbance of strata, which seem, on the contrary, to have been gently and gradually upheaved, often without fracture or dislocation for hundreds of miles. In the United States, there are no volcanoes, active or dormant. In South America, however, Central America, California, Mexico, and the West India islands, numerous volcanic vents exist.

With respect to aqueous or stratified rocks, we are apparently deficient in those strata lying in other countries below the chalk and above the new red sandstone, generally designated as the oolitic formations. It is not impossible, however, that this deficiency may yet be supplied by future observation and research.

Mineral salt, in regular and very thick strata, has recently been discovered near Abingdon, in Virginia. This constitutes an interesting feature of our geology; for while vast numbers of salt springs existed in different portions of our country, no solid mineral salt had been discovered east of the Rocky mountains.

The Appalachian or Ohio coal-field extends for a length of seven hundred and twenty miles from northeast to southwest, and its greatest width is about one hundred and eighty miles. That of Illinois, comprehending also parts of Indiana and Kentucky, is equal in dimensions to the whole of England, and consists of horizontal strata with numerous rich seams of bituminous coal. The coal is found in beds of considerable thickness; and in one instance there exists a bed of forty feet thick, coming up to the surface, and quarried like stone. "I was truly astonished," observes Mr. Lyell in his "Travels in North America," "now that I had entered the hydrographical basin of the Ohio, at beholding the richness of the seams of coal which appear everywhere on the flanks of the hills and at the bottom of the valleys, and which are accessible in a degree I never witnessed elsewhere. The time has not

yet arrived, the soil being still densely covered with the primeval forest, and manufacturing industry in its infancy, when the full value of this inexhaustible supply of cheap fuel can be appreciated; but the resources which it will one day afford to a region capable by its agricultural produce alone of supporting a large population, are truly magnificent. In order to estimate the natural advantages of such a region, we must reflect how three great navigable rivers, such as the Monongahela, Allegany, and Ohio, intersect it, and lay open on their banks the level seams of coal."

"Almost the whole surface of North America," observes Professor Rogers, "as far as examined, may be said to be covered with an investment of earth, pebbles, and boulders, obviously of diluvial origin. The thickness of this deposite varies, though its average depth may be said to be from ten to twenty feet. All that low and level tract described as the Atlantic plain, and also the lower sections of the great valley of the Mississippi, appear to be the districts where it conceals the underlying strata to the greatest depth. Over the whole of this extensive territory, it covers the horizontal strata of the tertiary and cretaceous deposites, and obscures them so effectually, that, except in the cliffs, along the rivers, and in the sides of the ravines and valleys, these formations are rarely or never exposed." On the Atlantic coast, this great mass of detritus consists of fine sand and gravel, which could only have been derived from the interior, above the range of rocks bordering the tide. Advancing inward from the coast the diluvial mass becomes coarser and less sandy, the soil somewhat less barren, and the vegetation more diversified. "Over the upper portion of the Atlantic plain," he continues, in another place, "or nearest its rocky boundary, the mass contains the gravel in a much coarser state, mingled with clay sufficiently pure for bricks.

Rolled blocks and boulders of no inconsiderable size occur, especially in the valleys of the rivers, when within ten or twelve miles of the boundary mentioned. For many miles from the coast, there is rarely anything but the diluvium. In the central districts of the tract, the fossiliferous strata, appear beneath it, though near the upper limits of this track these often disappear again, and the region immediately eastward of the rocky boundary presents the diluvium covering another class of deposites, very different from the tertiary and secondary; deposites which underlie it near the sea." Proceeding from the Atlantic plain toward the mountains, the diluvial matter is more irregularly distributed, in consequence of the undulations of the surface, and may be seen in the greatest quantity in the valleys of the rivers, the boulders which cover their beds and sides being almost invariably traceable to formations which lie at some miles distance to the north and northwest.

Dr. Drake, of Philadelphia, in a paper read before the American Philosophical Society, in that city, nearly twenty years since, entitled a "Geological Account of the Valley of the Ohio," after describing the gravelly substances or *debris* which occur in that region, and which are found of similar composition and character in the western and northern portions of the United States generally, gives it as his opinion that they originated in the north, and were brought and deposited on the surface of this country by currents which in ancient times flowed from beyond the lakes to the gulf of Mexico. "A more recent formation," he observes, "than many of the alluvial beds contained within these limits, is the stratum of loam spread over the surface of our hills and valleys in an overlaying position. This appears to be the same that M. De Luc considers as the last deposite made by the sea before its final retreat, and the last operation which

the waters of the north performed upon the region, and, of course, subsequent to the excavation of the valleys, as no deposite could have remained upon their acclivities while the agent which formed them continued its action. To this formation belong the great blocks which have ex cited in travellers so much astonishment, and which, in one point of resemblance at least, approximate the region south of the lakes so closely to that which stretches from the southern shores of the Baltic. The size of these masses extends from that of gravel and pebbles, to the diameter of eight or ten feet. I do not entertain a doubt that these fragments were enveloped in large fields of ice, in a region far beyond the lakes, and floated hither by the same inundations that brought down and spread over the surface of this country the *geest* in which they are imbedded. In the southern parts of this formation, they are not found: but this should be attributed to the influence of the climate. The ice to which they were attached, could not, of course, pass a certain latitude; and from the great increase of these masses as we advance toward the north, it would seem that many of the icebergs suffered dissolution long before they arrived at this maximum. Future observers will, no doubt, trace them to their parent strata in the arctic region, as Von Buch has traced those which are lodged on the shores of the Baltic. The ice-islands of the Atlantic ocean may reasonably be supposed to bring down and deposite on its bed in the temperate zone, primordial masses similar to those spread over some parts of this and the European continent."

From these facts and this mode of reasoning, it would seem that at some former period, the ocean flowed ovei this continent, with a current setting from north to south giving character to the present features of the country Mr. Hayden has pursued the same inquiry in regard to th rivers and soils on the Atlantic coast, with the same re

sult. "Let it be established," observes a writer in the North American Review, "that the rocky fragments deposited throughout the alluvial formations of this country, are of precisely the same kind as the primitive masses in the polar regions of the American continent, and the demonstration will approach a degree of certainty satisfactory to most minds."

Professor H. D. Rogers, however, in his address before the Association of American Geologists and Naturalists, at Washington, in 1844, inclines to the opinion that no general permanent submersion of the land took place as above supposed; but that one or more paroxysmal movements of the earth's crust in the higher northern latitudes, accompanied by energetic and extensive undulations of the surface, caused a rush of the northern waters, charged with ice and huge fragments of rock, in a succession of tremendous deluges southward across the continent.

The highly inclined and contorted appearance of a portion of the strata composing the lofty cliffs of Gayhead at the western end of the island of Martha's Vineyard, in New England, afford unquestionable proof of a great series of subterranean movements in this part of the American continent, between the miocene epoch and the boulder period. "The tertiary clays and sands of the island," observes Mr. Lyell, "are for the most part deeply buried beneath a mass of drift, in which lie huge erratic blocks of granite, often from twenty to thirty feet in diameter, which must have come from the north, probably from the mountains of New Hampshire. This covering of granite detritus imparts to the soil a sterile character, totally different from that which would naturally belong to the tertiary clays and marls."

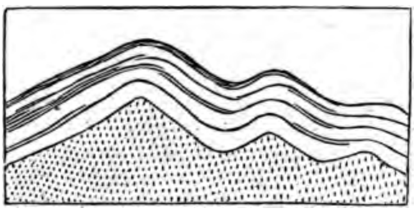
Immediately underneath this general investment of diluvium occurs a group of beds of no inconsiderable extent which, in their phenomena, seem to cast important

light upon the former revolutions of the Atlantic side of the continent—pointing to a period when this coast had a very different configuration, and denoting, in a striking manner, one of the revolutions which have impressed upon the tract included between the sea and the mountains, the peculiar feature which it now bears. It has evidently been formed under different circumstances from the other tertiary beds of the continent, and at a period apparently much more recent; and is termed by Professor Rogers, *ancient alluvium.* "Its beds," he observes, "consist generally of numerous alternating deposites of gravel, sand, various colored tenacious clays, often black and ferruginous conglomerates, iron ore, and lignite. They occur exposed in the deeper sections of our canals and railroads, and in the banks of some of the rivers, where they usually reach from the water's edge to an elevation of sixty, seventy, or more feet. They extend along the upper edge of the Atlantic plains ranging along the eastern base of the rocky Atlantic slope, in a belt several miles wide, and appearing at intervals, where the rivers have cut through them, from the coast of Massachusetts, as far at least, it is believed, as the Mississippi." Professor Hitchcock describes them under the name of the *most recent tertiary.* He, however, makes a distinction between these and other similar beds, which he denominates plastic clay. "The first," he says "are horizontal layers of white siliceous sand and blue plastic clay almost entirely destitute of organic remains. These beds constitute most of the level and elevated terraces along the valley of the Connecticut and other rivers of New England; the height of the plains above the water ranging from fifty to one hundred feet. In some places, the clay beds alone compose the cliff, and are from forty to more than seventy feet thick. They repose beneath fifteen or twenty feet of diluvial matter. Their position and

all their features, here and elsewhere, indicate a general uplift of the strata along the whole line of the primary boundary, when that boundary formed the coast, and a consequent emergence of these beds from about the water level where they seem to have grown as marshy deltas, accumulated along the ancient mouths of the rivers. On this supposition, the mouths of the Atlantic rivers were at the points where they now form their falls, and break through the boundary of the older rocks; and all the conspicuous deposites of these clays, imbedding the trunks of trees and lignite, are opposite to or near the same points."

The organic remains found in the various strata and formations of this continent correspond in genera, and many of them are identical in *species* with those found in the corresponding European strata.

The rocks of the Alleganies or Appalachian chain of mountains consist of the Silurian, Devonian, and carboniferous groups of the European formations, but appear to be folded as if they had been subjected to a great lateral pressure when in a soft and yielding state, large portions having been afterward removed by denudation.



"No traveller," says Mr. Lyell, "can fail to remark the long and uniform parallel ridges, with intervening valleys, like so many gigantic wrinkles and furrows, which mark the geographical outline of this region; and these ex-

ternal features are found by the geologist to be intimately connected with the internal arrangement of the stratified rocks. The long and narrow ridges, rarely rising more than two thousand feet above the valleys, and usually not more than half that height, are broken here and there by transverse fissures which give passage to rivers. The strata are most disturbed on the southeastern flank of the mountain chain, and become less and less broken and inclined as they extend westward."

"Starting from the shores of the Atlantic," observes the same writer, in his interesting description of the structure and origin of the Appalachian chain of mountains, "on the eastern side of the continent, we first come to a low region which was called the alluvial plain by the first geographers. It is occupied by tertiary and cretaceous strata, nearly horizontal, and containing in general no hard and solid rocks, and is usually not more than from fifty to one hundred feet high, from New Jersey to Virginia. In these states, this zone is not many leagues in breadth, but it acquires a breadth of one hundred and one hundred and fifty miles in the southern states, and a height of several hundred feet toward its western limits. The next belt consists of granitic rocks (hypogene), chiefly gneiss and mica-schist, covered occasionally with unconformable red sandstone, remarkable for its ornithicrites. Sometimes, also, this sandstone rests on the edges of the disturbed paleozoic rocks. The region sometimes called the 'Atlantic slope' corresponds nearly, in average width, with the low and flat plain whence it rises, and is characterized by hills of moderate height, contrasting strongly, in their rounded shape and altitude, with the long, steep, and lofty parallel ridges of the Allegany mountains. The narrow and parallel zones of the Appalachians, here mentioned, consist of strata folded into a succession of convex and concave flexures, subsequently laid open by denudation. The compo-

nent rocks are of great thickness, all referable to the Silurian, Devonian, and carboniferous formations. There is no principal or central axis, as in the Pyrenees and many other chains—no nucleus to which all the minor ridges conform ; but the chain consists of many nearly equal and parallel foldings, having what the geologists term an anticlinal and synclinal arrangement. This system of hills extends, geologically considered, from Vermont to Alabama, being more than one thousand miles long, from fifty to one hundred and fifty miles broad, and varying in height from two thousand to six thousand feet. Sometimes the whole assemblage of runs rises perfectly straight for a distance of more than fifty miles, after which all of them wheel round together, and take a new direction, at an angle of twenty or thirty degrees to the first.

"Mr. R. C. Taylor had made considerable progress in unravelling the structure of certain portions of this chain, before the commencement of the state survey of Virginia and Pennsylvania—the former conducted by Professor W. B. Rogers, the latter by his brother, Professor H. D. Rogers —both aided by a numerous corps of assistants. To these elaborate and faithful surveys we owe the discovery of the clue to the general law of structure prevailing throughout this important range of mountains, which, however simple it may appear when once made out and clearly explained, might long have been overlooked, amid so great a mass of complicated details. It appears that the bending and fracture of the beds is greatest on the southeastern or Atlantic side of the chain, and the strata become less and less disturbed as we go westward, until at length they regain their original or horizontal position. On the eastern side, or on the ridges and troughs nearest to the Atlantic, the southeastern dips predominate, in consequence of the beds having been folded back upon themselves—those on the northwestern side of each arch having been inverted. The

next set of arches are more open, each having its western side steepest: the next opens out still more widely—the next still more—and this continues until we arrive at the low and level part of the Appalachian coal-field.

"The movements which imparted so uniform an order of arrangement to this vast system of rocks must have been contemporaneous, or belonging to one and the same series, depending on some common cause. Their geological date is unusually well defined. We may declare them to have taken place after the deposition of the carboniferous strata, and before the formation of the red sandstone. The greatest disturbing and denuding forces have evidently been exerted on the southeastern side of the chain, and it is here that igneous or plutonic rocks are observed to have invaded the strata, forming dikes, some of which run for miles in lines parallel to the main direction of the Appalachians, or north-northeast and south-southwest. According to the theory of the Professors Rogers, the wave-like flexures above alluded to are explained by supposing the strata, when in a plastic state, to have rested on a widely-extended surface of fluid lava, and elastic vapors and gases. The billowy movement of this subterranean sea of melted matter imparted its undulations to the elastic overlying crust, which was enabled to retain the new shapes thus given to it by the consolidation of the liquid matter injected into fissures. For my own part, I can not imagine any real connexion between the great parallel undulations of the rocks, and the real waves of a subjacent ocean of liquid matter, on which the bent and broken crust may once have rested. That there were great lakes or seas of lava, retained by volcanic heat for ages in a liquid state beneath the Alleganies, is highly probable; for the simultaneous eruptions of distant vents in the Andes, leave no doubt of the wide subterranean areas permanently occupied by sheets of fluid lava in our own times. It is also consistent

with what we know of the laws governing volcanic action to assume that the force operated in a linear direction, for we see trains of volcanic vents breaking out for hundreds of miles along a straight line, and we behold long parallel fissures often filled with trap or consolidated lava, holding a straight course for great distances through rocks of all ages. The causes of this peculiar mode of development are as yet obscure and unexplained; but the existence of long, narrow ranges of mountains, and of great faults and vertical shifts in the strata, prolonged for great distances in certain directions, may all be results of the same kind of action. It also accords well with established facts to assume that the solid crust, overlying a region where the subterranean heat is increasing in extent, becomes gradually upheaved, fractured, and distended, the lower part of the newly-opened fissures becoming filled with fused matter, which soon consolidates and crystallizes. These uplifting movements may be propagated along narrow belts placed side by side, and may have been in progress simultaneously, or in succession, in one narrow zone after another. When the expansive force has been locally in operation for a long period, in a given district, there is a tendency in the subterranean heat to diminish: the volcanic energy is spent, and its position is transferred to some new region. Subsidence then begins, in consequence of the cooling and shrinking of subterranean seas of lava and gaseous matter: and the solid strata collapse in obedience to gravity. If this contraction take place along narrow and parallel zones of country, the incumbent flexible strata would be forced, in proportion as they were let down, to pack themselves into a smaller space, as they conformed to the circumference of a smaller arc. The manner in which undulations may be gradually produced in pliant strata by subsidence is illustrated, on a small scale, by the creeps in coal-mines: there both the overlying and under-

lying shales and clays sink down from the ceiling, or rise up from the floor, and fill the galleries which have been left vacant by the abstraction of the fuel. In like manner, failure of support, arising from subterranean causes, may enable the force of gravity, though originally exerted vertically, to bend and squeeze the rocks, as if they had been subjected to lateral pressure.

"'Earthquakes have raised to heaven the humble vale,
And gulfs the mountain's mighty mass entombed—
And where the Atlantic rolls, wide continents have bloomed.'

"In applying these lines to the physical revolutions of the territory at present under consideration, we must remember that the continent which bloomed to the eastward, or where the Atlantic now rolls its waves, was anterior to the origin of the carboniferous strata which were derived from its ruins; whereas, the elevation and subsidence supposed to have given rise to the Appalachian ridges, was subsequent to the deposition of the coal measures. But all these great movements of oscillation were again distinct from the last upheaval, which brought up the whole region above the level of the sea, laying dry the horizontal new red sandstone, as well as a great part, if not all, of the Appalachian chain.

"The largest amount of denudation is found, as might have been expected, on the southeastern side of the chain, where the force of expansion and contraction, of elevation and subsidence, has been greatest. The first set of denuding operations may have taken place when the strata, including the carboniferous, were first raised above the sea; a second, when they sank again; a third, when the red sandstone, after it had been thrown down on the truncated edges of the older strata, participated in the waste. The great extent of solid materials thus removed must add, in no small degree, to the difficulty of restoring in imagina-

tion the successive changes which have occurred, and of accounting in a satisfactory manner for the origin of this mountain-chain."

"It is very probable that the Silurian, Devonian, and carboniferous strata which enter into the composition of the Appalachians, underwent the principal movements of upheaval and subsidence to which their prevailing structure is due, at a time when they were still submerged beneath that ocean in which they were originally formed—for that they were at first marine deposites, is testified by their imbedded corals and shells. It is therefore certain that they have undergone some elevation before they arrived at their present position. But we can not infer from this fact that movements of elevation rather than of subsidence have been most effective in impressing upon them their present structure. From the fact that nearly horizontal beds of newer red sandstone are found to rest unconformably on the inclined strata of the Alleganies, it is obvious that the last series of movements which upraised this continent was quite distinct from those prior movements which threw the ancient strata into their inclined and curved position."

Speaking of the bed of anthracite at Maunch Chunk, or the Bear mountain, in Pennsylvania, Mr. Lyell remarks: "The vegetable matter which is represented by this enormous mass of anthracite must, before it was condensed by pressure and the discharge of its hydrogen, oxygen, and other volatile ingredients, have been probably between two hundred and three hundred feet thick. The accumulation of such a thickness of the remains of plants so unmixed with earthy ingredients, would be most difficult to explain on the hypothesis of their having been drifted into the place they now occupy; but it becomes intelligible if we suppose them to have grown on the spot. Whether we regard the *stigmariæ* as roots, according to the opinion of

M. Adolphe Brongniart and Mr. Binney, or embrace the doctrine of their being aquatic plants, no one can doubt that they at least are fossilized on the very spot where they grew; and as all agree that they are not marine plants, they go far to establish the doctrine of the growth *in situ* of the materials of the overlying coal-seams.

"The prodigious thickness of the carboniferous rocks in this part of the Appalachian chain is in harmony with the theory already alluded to, which requires the repeated sinking down of many successive terrestrial surfaces, allowing an indefinite quantity of sediment to be superimposed vertically in one continuous series of beds. The surveys of Pennsylvania and Virginia show that the southeast was the quarter whence the coarser materials of the carboniferous rocks were derived, and there are proofs that the ancient land lay in that direction—the deep sea with its banks of coral and shells to the west."

The anthracite coal measures occurring in the eastern or most disturbed part of the Appalachian chain are fragments or outliers of the great continuous coal-field of Pennsylvania, Virginia, and Ohio, about forty miles westwardly. This coal-field is remarkable for its vast area, extending continuously from northeast to southwest a distance of seven hundred and twenty miles, its greatest width being one hundred and eighty miles, and occupying a superficial area of upward of sixty-three thousand square miles.

With the exception of the unconsolidated superficial recent deposites, occupying a very limited area, all the rocks of the state of New York are older than the coal formation—belonging either to the unstratified crystalline, the primary of older writers—the stratified non-fossiliferous—or to the older secondary fossiliferous strata, terminating in the lowest member of the coal formation, on the highest elevations, near the Pennsylvania line. The question, therefore, as to the existence of coal within the boundary

of the state is fully and conclusively settled in the negative; and the knowledge of this fact will effectually prevent the investment of further labor and capital in the fruitless search for this mineral in our borders. Its existence, however, in inexhaustible abundance, near the state line in Pennsylvania, affords an ample compensation when we take into account the constantly increasing facilities for transportation which modern enterprise is engaged in supplying.

The non-fossiliferous rocks of the primary system, both crystalline and stratified, are confined within an irregular circular area in the northeast, and a small triangular corner in the southeast, comprising in the whole about one third of the area of the state. The prevailing rocks in this series are gneiss, mica-schist, talcose slate, and crystalline limestone. Granite exists, but it is quite unimportant both in extent and value. The *hypersthene* series of rocks, traversed by large and valuable beds and veins of iron ore, extends over nearly the whole of Essex county. Primitive limestone, serpentine, hornblende, sienite, talc, porphyry, and trap, are found in the northern portions of the state. Of these, the hypersthene rock and the primary limestone are the most important—the former for its rich supply of iron ore, and the latter for agricultural purposes. On the extreme eastern boundary of the state, and extending into Vermont and Massachusetts, we find the *Taghkanic range* of the Appalachian chain, between the New England primary on the east, and the lowest fossiliferous rocks of New York on the west. These rocks are supposed to be the equivalents of the lower Cambrian of Professor Sedgwick—the lower Silurian of Mr. Murchison. Their most important economical products are the white and clouded marbles furnished by the calcareous beds, and the white siliceous sand for glass and sand-paper, and for sawing marble, procured from the granular quartz of this forma-

tion. No instance of any description of injected rocks has been discovered in this system—whence it is reasonable to infer that few if any disturbances have occurred since the general elevation of the surface.

The older fossiliferous rocks, occupying the entire area between the great northern and western lakes and the southern boundary of the state, and comprising at least two thirds of its extent, form the characteristic features of its geology, and have hence received their distinctive designation as the *New York system.* The *Potsdam sandstone*, forming the base of the Champlain group of this system, is the oldest fossiliferous rock yet discovered in the United States. In an economical point of view, however, the *Ontario division* is the most important—furnishing, as it does, an abundant supply of plaster, water-lime, and salt-water, besides affording fine deposites of fossiliferous iron ore. The middle beds of this division correspond with the base of the upper Silurian system of England.

The carboniferous, oolitic, and cretaceous systems of the eastern hemisphere are entirely wanting in our formations. as is also the tertiary, in the usual acceptation of the term, The new red sandstone is partially developed in the southeast.

There are two primary regions in the state, separated from each other by the intervention of a narrow belt of sedimentary rocks; one in the northern part of the state, terminating at Little Falls, composed of hypersthene rock, granite, serpentine, primitive limestone, gneiss, and sienite, nearly circular in its form and surrounded by transition rocks; the other in the southern and southeastern portion, of comparatively small extent, and embracing the southeastern part of Orange county, including in its more elevated portions the Highlands, and parts of Columbia, Dutchess, and Rensselaer counties, adjacent to the Hudson river, on the east. In addition to the rocks

above enumerated, mica and talcose slate are found in this region.

The Adirondack group of mountains, the highest in the state, is composed of a peculiar kind of granite—dark-colored and coarsely crystalline—unstratified, although traversed by natural joints similar to the common granite. This rock has been denominated hypersthene; this mineral constituting one of its elements. Some of its varieties are of a light color; others, gray and dark. The hypersthene rock is limited in extent chiefly to the county of Essex.

Granite, as has heretofore been observed, constitutes a very unimportant part of the primary formations of the state; occurring only in limited areas, and seldom of a quality suitable for building. It is found in portions of St. Lawrence county, and at intervals of greater or less extent throughout the primary region; associated usually, and frequently mechanically combined with the primitive limestone. In the southern primary district, it presents numerous varieties of texture from a coarse-grained to a perfectly compact rock; and is commonly found in beds, interstratified with gneiss. This species of rock, of a quality equal to the granite of Massachusetts or Maine, is abundantly developed in the counties of New York, Putnam, Westchester, and Orange.

Serpentine, occasionally incorporated with the primitive limestone, and in some places with iron ore, is of frequent occurrence in the primary regions. Veins of limestone are sometimes found penetrating the superincumbent granite, although in general, the primitive limestone occurs in connexion with and sometimes immediately under this rock. Its most extensive development is in St. Lawrence county; and its igneous origin is manifest from the incorporation with it of various min-

erals, such as plumbago, serpentine, quartz, mica, and augite.

The predominant rock, both in the northern and southern primary regions of the state, is gneiss, varying, however, in appearance and composition, in different sections. In the Highlands, it assumes the shape of sienite; as a system, it embraces gneiss, sienite, mica-slate, hornblende, talcose slate, and other stratified rocks.

The rocks of the Taghkanic range of mountains, on the eastern border of the state, adjacent to Vermont, Massachusetts, and Connecticut, rising to an elevation of nearly two thousand feet, may also be regarded as belonging to the primary formation. They are composed of a peculiar talcose or magnesian slate, white, gray, and clouded limestone, varying in texture from fine to coarse granular, frequently interlaminated with slate, and granular quartz, or brown silecious sandstone, occasionally interspersed with beautiful white quartz in a disintegrating state. The most important and at the same time most abundant of the valuable minerals found in the primary rocks is iron ore. No deposites of the ores of lead, zinc, or copper, in any valuable quantity, have as yet been discovered. In the transition rocks, salt, water-lime, and plaster, are found in abundance. The lowest rock of the coal formation occupies some small patches in the southwestern part of the states; but none of the coal-bearing strata approach nearer than within six miles of the state line.

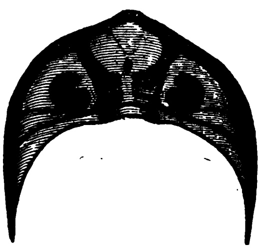
"Surrounding the entire region of primary rocks," observes Professor Hall, "there was first a siliceous deposite and subsequently a calcareous one, in the latter of which are imbedded myriads of corals, crinoidea, shells, &c. All these are the inhabitants of an ocean, and all are imbedded in limestone and slate, the former produced partially from the broken remains of marine animals, and

partially also from other sources. The rocks of this formation are described in the reports under the name of Black River and Trenton limestones, from their great development on the Black river, in Jefferson county, and at Trenton falls, in Oneida county. The beautiful cascades and magnificent scenery, at Trenton falls, are produced by the upper of these limestones, through which the stream has cut its way for several miles, passing over six successive falls.

"That singular race of animals, known as trilobites, also flourished at this period, and their remains abound in many of the strata. In the investigations made in New York, these animals are shown to have been among the earliest created things, and very few indeed preceded them."

The rocks from which this species of fossils is derived, are nearly at the bottom of the series, and above them are other rocks, each containing its organic remains, its fossils, corals, shells, and trilobites. The following are specimens of the most common kinds, although they are usually found only in fragments.

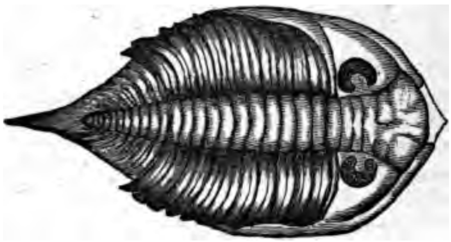
1



2

1. Head of Asaphus limulurus.   2. Calymene Niagarensis.

3



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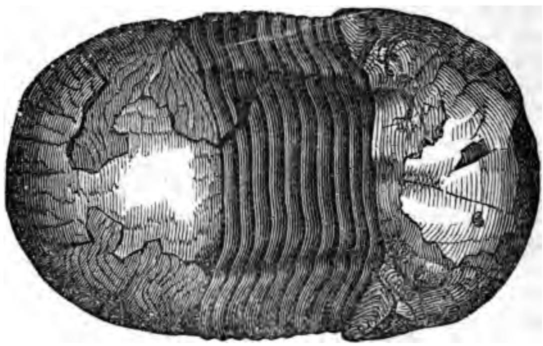


3. Asaphus limulurus. 4. Bumastis Barriensis.

" There is one thing which should be early impressed ; a principle inculcated throughout the geological reports, and founded in nature. *Every rock contain fossils peculiar to itself, and which do not appear in any other.*

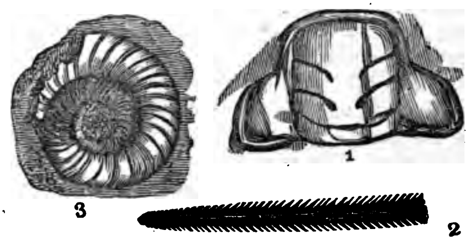
"Perhaps it may be asked of what practical application is this knowledge ? But we shall readily see ; for in the same geological position over the extent of the entire continent, the same fossils are found. If there were any mineral substances, which we were seeking in the rocks

above or below the one in which a given series of fossils was found, these fossils would be the most unerring guides, and the landmarks on which we could always rely. The same rule holds good when we approach the coal-bearing strata, and organic remains become the sure guides in our search after these rocks. The evidence, when once acquired, is applicable over entire countries, and indeed over the entire globe: and a geologist relies upon them with the same certainty and security that a miner does upon boring into the solid strata."

"Such is a glance at the practical use of organic remains. Viewed philosophically, they present us the chain of creation from the most remote periods, when the vital principle first assumed its prerogative on earth, through incalculable ages up to the present time. Geology, founded on the succession of organic remains, presents one of the most beautiful systems of natural operations in the visible creation. The beauty and harmony here displayed should be enough to move the most indifferent to regard such things. When we reflect, also, that by this means we are enabled to know at all times and in all places, our geological position; our latitude and longitude, as it were; and to know what resources are within our reach from these objects, it then becomes a subject worthy the utilitarian, and aiding him in his pursuits, is an accessory to more physical investigations."

The limestones to which we have above referred are succeeded by a black shale, common in the Mohawk valley, containing but few fossils of which those in the annexed cut are most common, and on which the city of Utica is built; from which it has received the name of Utica slate.

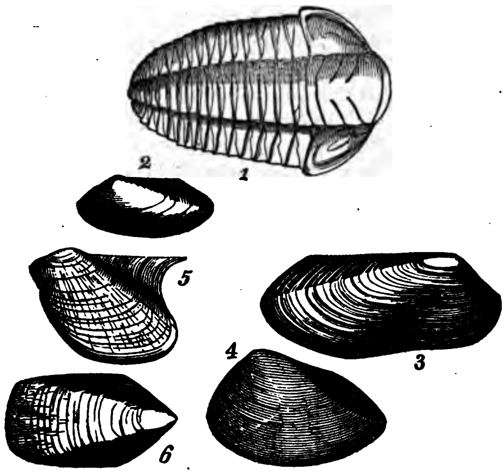
This is succeeded by shales and sandstones, a formation accompanied in many instances by the most beautiful and attractive scenery. "In Oswego and Lewis counties,"



1. Head of Triarthrus beckii. 2. Graptolites dentatus.
3. Trocholithus.

continues Professor Hall, in the sketch to which we are principally indebted for the details of these successive formations, "and in the southern part of Jefferson, they are indented by long and deep ravines, with almost vertical sides, winding their course from the highest part of the country down to the level of the limestone platform on which they rest. These rocks, which in the north-western part of the state present this regular and uniform appearance, are the same as those along the Hudson river, from Washington county to near the Highlands. Here, however, instead of presenting this regular structure, they are twisted and contorted, often standing on their edges, and frequently so disturbed that the strata can scarcely be followed. It is in these rocks along the Hudson river that so much search has been made for coal. The slate or shale, having often a smooth and shining appearance, or, as it is termed, glazed, and breaking out in irregular masses, gives to the inexperienced, a hope of finding coal. No excavation, however, proves anything more than can be seen upon the surface; the whole mass consists of similar materials, the carbonaceous matter being barely sufficient for coloring the rock. It is much to be desired that this idle search for coal should cease,

and every man having confidence in the results of scientific investigation should exert himself to suppress it. Nothing can be more certain than that this rock is very remote from any coal-bearing strata, and from repeated investigations of its whole thickness, it is quite evident that no coal can exist in it. It is the same rock in which excavations have been made in some places in the valley of the Mohawk, and with the like success to that in the Hudson valley. Many specimens and boxes of the same glazed slate have been sent to different individuals, and to the state collection, under the name of coal, with a request to give an opinion as to its value, which is no more than that of common clay. The nature of the fossils, common to the rock, afford, of themselves, conclusive evidence that the strata are remote from the coal-

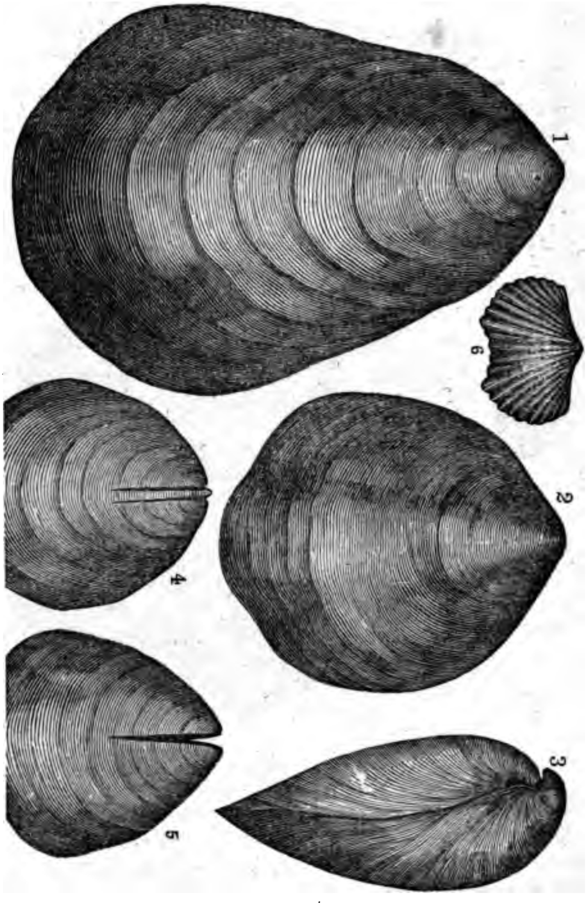


1. Triarthrus beckii. 3. Cypricardia sinuata. 5. Avicula.
2. Nucula scitula. 4. Nucula poststriata. 6. Lingula rectilateralis.

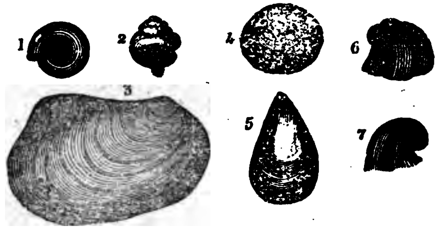
bearing rocks, which always contain the remains of vegetables, such as ferns and the like, while in these rocks no such fossils are ever seen."

"The rock succeeding this group is one of gray sandstone, or a conglomerate of quartz, pebbles, and sand. It resembles, in general character, the millstone grit of England, a rock associated with the coal measures; and from this circumstance it was, many years since, supposed to be connected with similar strata in New York. The investigations during the geological survey have for ever set at rest this question, by proving it to be far below any coal-bearing strata.

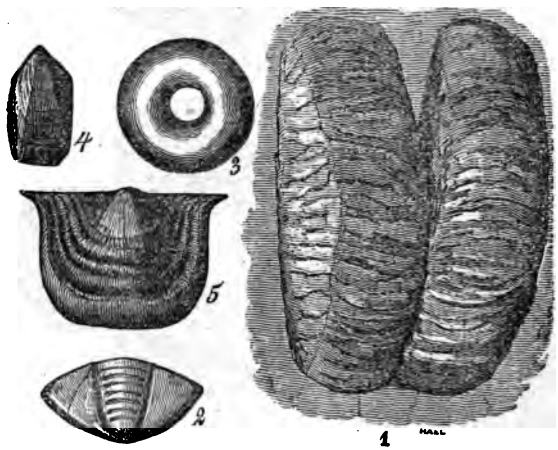
Following this rock, and associated with it, we have a red and variegated sandstone, which borders Lake Ontario, from the Oswego river to the Niagara. From its resemblance to the new red sandstone of Europe, and from containing brine-springs, it was once regarded as its equivalent, and it was even supposed that coal would be found by boring through it. This erroneous opinion arose from depending upon the mineral nature of the rock, and from the presence of brine-springs, which occur in the new red sandstone of Europe, a rock overlying the coal measures. The brine-springs of this rock, however, have generally proved too weak, or the quantity of water too small, for profitable exploration; and the geological survey has shown that this is not the position of the true salt formation of the state. This rock presents some interesting scenery, forming the falls on the Oswego and Genesee rivers, and the fall at Medina on Oak-Orchard creek, and again appearing in the banks of the Niagara at Lewiston, and at the Whirlpool. The picturesque fall at Medina occurs at a point where the naturalist will find this rock rich in fossils, it being generally nearly destitute of them in other places. Among the most remarkable, we find the *Fucoides Harlani*, which have the appearance of roots



1—5. Pentamerus oblongus. 6. Delthyris brachynota.



1 and 2. Euomphalus pervetustus. 3. Cypricardia alata.
4. Orbicula parmulata. 5. Lingula cuneata.
6 and 7. Bellerophon trilobatus.



1. Fucoides biloba. 2. Tail of Hemicrypturus. 3. Crinoidal joint.
4. Lingula oblonga. 5. Strophomena depressa.

branching in various directions and covering large surfaces. It was probably a marine vegetable, like the sea-weeds, which grew upon the bottom, and was covered with mud. This rock in some places furnishes valuable

building-stone; while in others, from the admixture of argillaceous matter, it is entirely unfit for any useful purpose where exposure is required.

"The succession of strata above the Medina sandstone, known as the Clinton group, is interesting, from containing extensive beds of iron ore, which are worked in Oneida and Wayne counties, and furnish good iron. One of these beds appears on the Genesee river, beyond which it can not be traced. One portion of this rock is marked by the presence of a peculiar fossil—the *Pentamerus oblongus*. In many places this shell is abundant, forming almost the entire mass of the rock, while in other places it is only sparingly scattered. An interesting fact connected with this shell is, that it is found in England in precisely the same geological position, and specimens from these can scarcely be distinguished from those at the lower falls near Rochester. This is another example illustrating the wide distribution of fossil species, and the reliance which may be placed upon them. Further east, this fossil disappears, and several others are found, among which are some vegetable remains.

"The cataract of Niagara presents us with a beautiful exhibition of the succeeding formation, which consists of shale and limestone. The same rock forms the upper falls at Rochester, and the fall at Wolcott, in Wayne county. The outcropping edge of the limestone forms the escarpment or terrace, which, in New York, extends from near Rochester to the Niagara river, and continues beyond, far into Canada. To this limestone we may look for some of the finest building-stone in the state; and the work on the enlarged locks at Lockport will bear comparison with any other in or out of the state. The great thickness at which the stone may be obtained, giving great weight, which is of primary importance in works exposed to frost, renders it a desirable stone for such uses. This limestone is the

repository of the beautiful spars found at Lockport and Niagara falls; and the shale below it is filled with beautiful organic remains. When we pass westward, this rock becomes metalliferous in the highest degree, containing all the productive lead-mines of Illinois, Wisconsin, and Iowa. The singular and beautiful fossils known as *encrinites* are more abundant in this group than in any other within the state. Some of the species are abundant at Lockport, but are rarely found east or west of that point.

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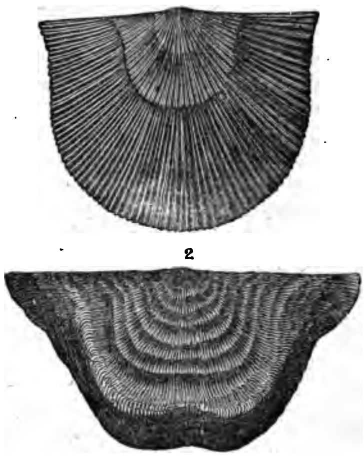
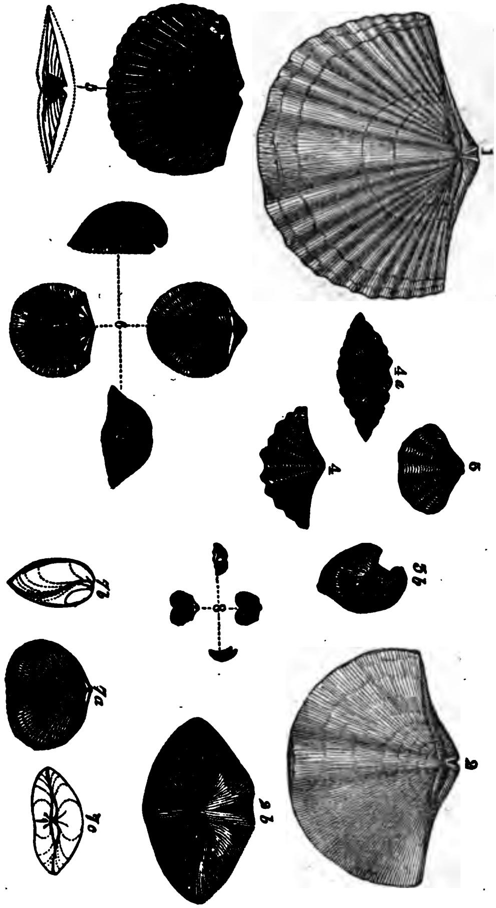


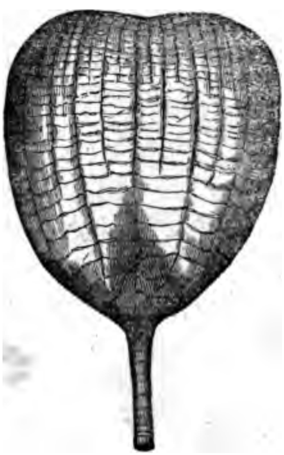
2

1. Strophomena subplana. 2. Strophomena depressa (lower valve).

"The *Onondaga salt group*, which follows the Niagara group, is one of the most important in all the series in New York. All the copious brine-springs in the state have their origin in these rocks, the extent and development of which



1. Delthyris Niagarensis.
2 and 2 b. D. radiatus.
3 and 3 b. D. staminea.
4 and 4 a. Delthyris decemplicata.
5. Orthis Flabellulum (a)?
6. Orthis canalis.
7. a. b. c. Orthis hybrida.
8. Delthyris sinuatus.



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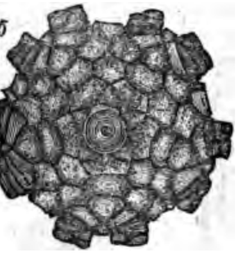

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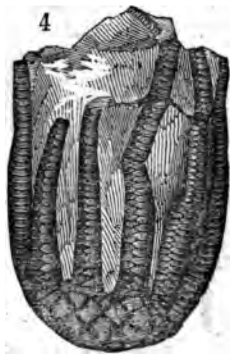
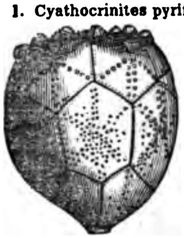


1. Cyathocrinites pyriformis

4 and 5. Marsupicrinites (?) dactylus.



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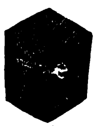

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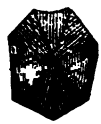

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7

4. Caryocrinus ornatus.

5 and 6. Costal plates, the internal surface.

7. A portion of one plate magnified, showing pores on the edge.

have been pointed out, so that borings and excavations can be undertaken with a knowledge of their position. Besides the salines, this group of rocks is important as furnishing all the gypsum of importance within the state; and this article alone may be regarded as of more pecuniary value than all the gold-mines in the Union. The gypsum-beds often occur in such a manner as to give an idea that they were formed subsequent to the consolidation of the strata. The lower range of plaster-beds are of flattened spherical form, and usually not very extensive. In the second range, the masses are of conical form and often very extensive, though the layers above them are not as much broken as in the lower range. The fossils of this group are exceedingly rare, though some have been detected in a few localities.

"We next find a series of rocks which in the eastern part of the state form the Helderberg mountains, the limestones about Schoharie, thence extending westward through Cherry Valley to Onondaga and Cayuga counties, and forming the low escarpment thence to the Niagara river at Black Rock. In this series of rocks are found some of the finest building-stone in the state; and the quarries of Onondaga have long been known and regarded as of the first importance in the construction of public works. The facility with which these stones are quarried is a subject interesting to all practical men. The layers are found with cracks or fissures penetrating them vertically to great depths; these fissures cross each other obliquely, dividing the rock into rhombic blocks. In this way large masses are easily removed, the vertical joint forming the back of the quarry. Extensive caverns occur in the rocks of this series, and the famous caves of Schoharie and its vicinity are in these limestones. The water thus finding its way into the fissures of this rock, becomes charged with carbonate of lime, and many important formations of marl

and tufa are the result where the water again comes to the air. Streams of considerable magnitude, in passing over these rocks, are often lost in the fissures, and reappear at some distant point. The lowest member of this series is the water-lime or hydraulic-cement rock, which, throughout the whole length of the state, furnishes this valuable cement. Its fossils are few. The second member is known as the pentamerus limestone, from the peculiar fossil of that name which it presents. A shaly limestone, known as the delthyris, is another member of the series, and abounds in peculiar fossils. To these, and one or two subordinate masses, follows a sandstone, or in some places an admixture of sand and lime, abounding in fossils. Wherever the rock is sandy, there the shells are dissolved, leaving only casts; and where the rock is calcareous, there we find the shells themselves remaining. This rock offers a good example of the variable thickness in sedimentary deposites at distant points. In this state, it is nowhere more than thirty feet thick; while in Pennsylvania it has a thickness of seven hundred feet, still containing the same fossils, and marked by the same or similar characters. The rock, though called a sandstone, is not an aggregation of particles of sand, but consists of a granulated mass of silica, which was evidently held in solution and precipitated from the fluids. In some places the calcareous matter was also held in solution, mingled with the silica, forming a hard and tough silico-calcareous rock. In going westward, this rock entirely disappears. It is rarely of sufficient thickness in New York to give any prevailing character to the soil.

"Following this, we have two thin masses of grit rocks, or those composed of sand and lime; but which exert no important influence upon the soil or character of the surface. These are the Cauda-galli and Schoharie grits—the former containing few fossils, except some apparently

vegetable remains, while the latter abounds in fossils. To these follow two limestones, termed in the reports the Onondaga and corniferous limestones. The former of these abound in corals and other fossils, and the rock often appears to be made up of the broken fragments. The extensive quarries north of Syracuse, before alluded to, are opened in this rock. Many of the corals seem as perfect as at the time they were living in the ocean; large masses often stand in the same position in which they grew, surrounded with the broken fragments of others. Again, they are overturned, or lying upon their sides, showing the action of waves of the ocean in transporting and overturning them. Some of these corals are still in their original state, presenting a honeycomb appearance, and are known generally as petrified honeycomb. In others the cells are filled with calcareous matter, and present solid columns. In other situations we find different kinds, termed petrified horns, but in reality corals growing in this form, starting from a small point, and expanding above into a cup-shaped disk. Many of these corals of both kinds have become changed to silex; and from being harder than the surrounding rock, which is worn away, they are left in relief or entirely dissolved out. From this cause we find great numbers of the corals in large and small masses scattered over the surface of the ground.

"The succeeding limestone differs from the last in being finer-grained and containing fewer corals; but principally in the presence of chest or hornstone which is scattered through it in irregular nodules or layers. This substance being so much harder than the surrounding rock, is left in jagged and irregular surfaces, and receives the name of *chawed rock*, in the western part of the state. Along the surface where this rock occurs, the soil is very stony and apparently barren; but still, although there is little fine soil visible, it yields good crops, and the decomposing

rock constantly acts as a fertilizer. This is the highest rock of that terrace of limestones which may be traced from Black Rock, on the Niagara river, to Albany county. When this rock approaches the surface, its decomposition forms an excellent road, and in many places its proximity would admit of its being carried further north and south, to situations which, from the nature of the rock, are in wet weather very muddy. A covering of this broken, flinty rock would be far better than any gravel which could be procured. When we trace this rock over the states of Ohio, Indiana, and Kentucky, we find it containing the same fossils, and the trilobites as abundant there as in New York. The breaking up of the edges of these limestone strata have produced an extremely fertile soil, and mingling with the veins of the shaly deposites further south, constitutes a belt of ten to fifteen miles in width, which stands unrivalled in fertility. This range of limestones is the most southern belt of calcareous rocks in the state—the thin bands following them exerting but little influence upon the soil. Viewed in this light, the Helderberg range of limestones exert an important influence upon the agricultural character and productions of a broad belt, extending from the Hudson to the Niagara river. If the farmers of New York, situated within the range of this influence, could see depicted upon a map the great expansion of these limestones in the western states, and their junction with other calcareous rocks, they would not be surprised at the wide and uninterrupted fertile regions of the west. These circumstances alone give to that portion of the country a pre-eminence in agriculture which no artificial means can give to any other portion of the continent.

"After leaving these limestones, we find in New York, ranging along their southern border, a series of shales, known as the Marcellus shale and Hamilton group, with

a few thin, calcareous bands, and finally passing into sandy varieties. The lower member of this series is a fine-grained black shale, and from being often highly bituminous, and sometimes glazed, like those along the Hudson river, has given rise to excavations for coal throughout its whole extent; and there is scarcely a town along its range where some excavation or boring has not been made in search of coal. Like all other searches of the kind in New York, these have always proved fruitless, and must ever prove so. The organic remains of this rock are few. Above this black shale the rock is lighter-colored, and in the eastern part of the state often somewhat sandy, while in the western it is a soft, argillaceous shale, rapidly crumbling on exposure to the air, and forming a clayey soil of great fertility. Where the rock approaches the surface, the soil is wet, but is excellent meadow-land. This rock, in

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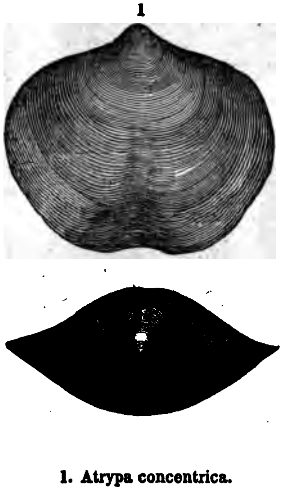

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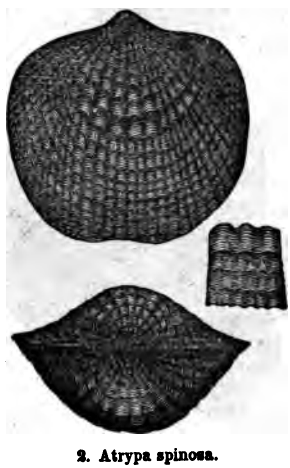
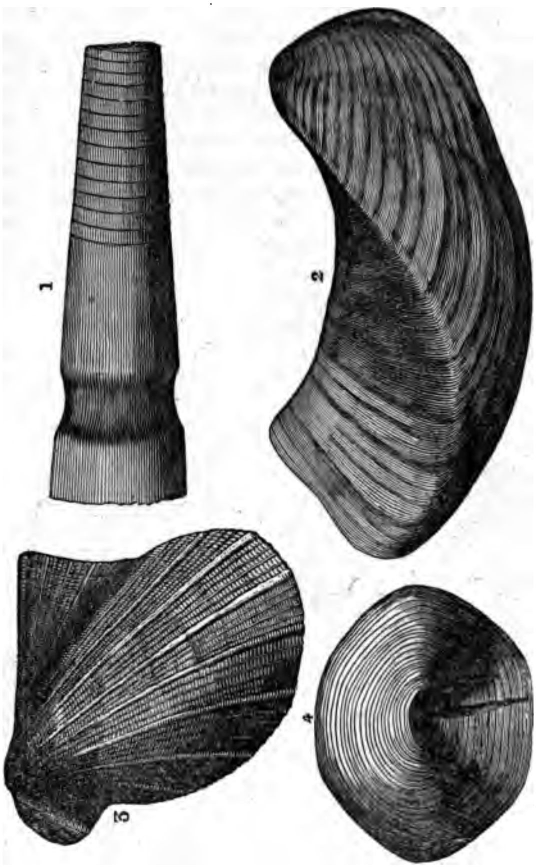


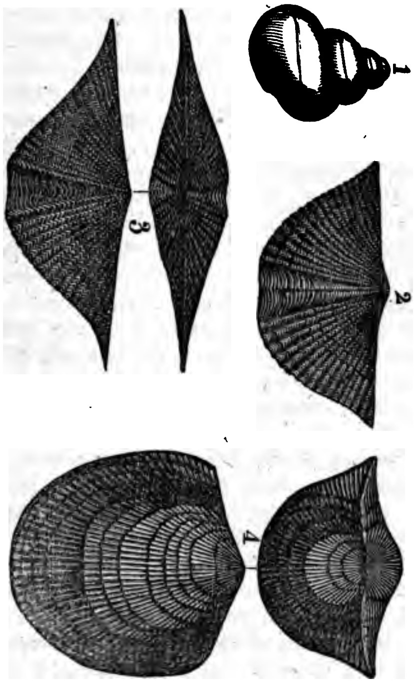
1. Atrypa concentrica.

2. Atrypa spinosa.



1. Orthocerus constrictum. 2. Cypricardia incurva. 3. Avicula flabella. 4. Orbicula grandis.

all its subdivisions, abounds in fossils, and perhaps no rock in the state contains an equal number. In the eastern part of the state these shales form elevated hills to the southward of the Helderberg limestone-range. As we go west, the shales become softer and more destructible, the



1. Turbo lineatus. 2 and 3. Delthyris mucronata. 4. Atrypa prisca.

hills gradually subside, and in the western counties they occupy for the most part a low position. This is particu-

larly the fact through Genesee and Erie counties and much of Livingston. Being thus denuded, they afford a place of lodgment for the calcareous gravel which has been transported from the northward.

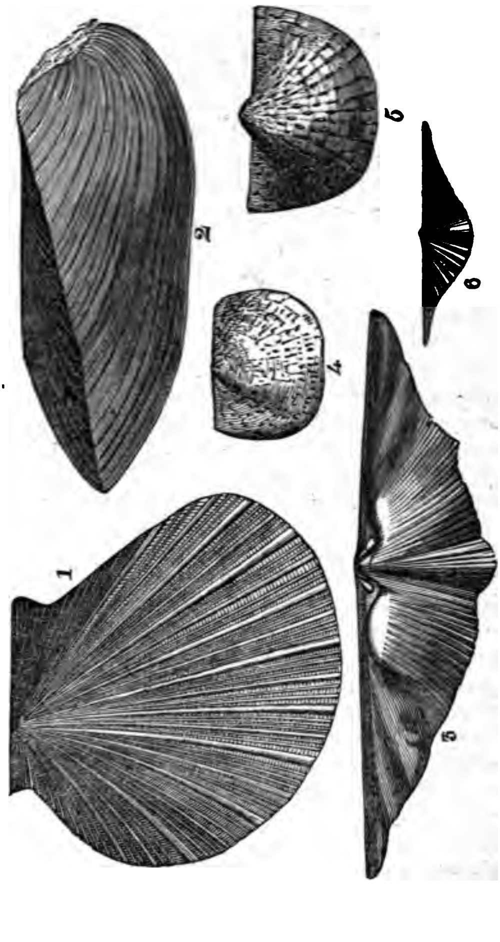
"The shales last described are often terminated by a band of limestone, known as the Tully limestone, to which follows the Genesee slate and Portage group, consisting of shales and sandstones, with a few fossils, and almost destitute of calcareous matter. As a consequence of this change in the character of the rocks, and concomitantly of the soil, we find pasturage taking the place of grain-growing, and the overflowing dairies and well-fed stock, are the equivalent of the wheat-stacks and granaries of the geological formations farther north. This change is marked and obvious, and one can not but be struck with it, whether or not he reflects upon the causes.

"We here observe that the pursuits of the inhabitants, though all depending on the soil, differ essentially upon different geological formations; and the farmer who would pursue the same system upon the hills of Allegany county, as in the lower valley of the Genesee, would fail entirely, the nature and condition of the soils in the two places, differing in very important particulars. This rule applies, not only to the formations in question, but to all others where the nature of the two differ in any essential degree. It often happens, however, that the materials of the more northerly rock have been drifted southward, giving the same character to the soil for some distance beyond where the rock is visible. This, however, forms no exception nor objection to the rule.

"The upper part of this group being composed of sandstone of a much harder nature than the lower part, produces cliffs and falls of water in all the streams passing over it; such as the falls of Portage, Hector falls, and numerous others. The highest fall of water in the state

is over a sandstone of this group. The fall is known as Taghannuck, on the western side of Cayuga lake; its perpendicular height is one hundred and ninety feet, being about thirty feet higher than Niagara. There are other and numerous cascades in this group, and there is scarcely a stream flowing to the north, where we do not find one or more falls of water. Although the rocks of this group have a thickness of 1,000 feet or more, still they contain very few fossils. The soil is a tough clay, constituting, however, a very good grass land.

"The succeeding group of rocks occupies nearly all the southern range of counties: and is termed, from its great development in Chemung county, and along the river of that name, the Chemung group. Like the last, it is composed of shales and shaly-sandstones, and one of the most distinguishing features of the group, and of the soil derived therefrom, is the absence of calcareous matter. Some of the other earths and alkalies essential to the production of grain are also absent from the soil, and the principal resource of the country is pasturage. Oats and the lighter grains flourish, and spring wheat produces tolerably well in the valleys, but the product of grain is insufficient for the consumption of the inhabitants. It is upon the hills formed by the rocks of this group that the waters divide; some of the streams flowing into Lake Ontario, and thence mingling with the ocean, in the gulf of St. Lawrence; others flow into it by the Delaware and Susquehannah; while those tributary to the Allegany, unite with the Atlantic, in the gulf of Mexico. The mineral resources of this portion of the country do not extend beyond common quarry-stones, of which nearly every farmer has a sufficient supply upon his own premises. The general outline of the country is hilly, and along the rivers and streams the banks are often abrupt, and sometimes cliffs of one or two hundred feet



1. Avicula tricostata. 3. Delthyris prolata. 5. Strophomena membranacea (upper valve).
2. Cypricardia chemungensis. 4. Strophomena membranacea. 6. Delthyris acuminata.

are presented where the out-cropping edges of the strata can be examined with great facility. In these rocks we begin to find more decided evidences of the existence of land plants; and the ferns approach in character to those of the coal period.

"Above these rocks, we have another series, consisting of red shales and sandstones, which form the greater part of the Catskill mountains, and thence spreading westward into Delaware, Chenango, and Broome counties. These have received the name of the Catskill group; and the whole is equivalent to what is known in Great Britain as the old red sandstone. The soil, from the decomposition of the rocks of this group, forms a reddish clay; and, though generally unproductive in grain, it is one of the best grazing districts, and the butter and cheese of the region occupied by these rocks are held in high estimation. These rocks gradually diminish in thickness on going westward, and are not seen west of the Genesee river. Their organic remains differ essentially from those below. Remains of fishes are more common than any other; indeed, but one species of shell is known in these rocks, in New York.

"By reference to the order of succession among the strata, it will be seen that we have arrived at that period when the coal formation commenced; that in all the previous formations, the organic remains are mostly marine, with rarely a few land plants, which may have drifted into this ancient ocean from neighboring islands or continents. At the coal period, however, there appears to have been an immense amount of vegetation buried beneath the accumulated sand and mud. The extensive coal beds are composed of vegetable matter, and myriads of ferns and other plants are scattered throughout the superincumbent strata. Here appears to have been the remains of the first creation after the surface of the

present continent became filled to support vegetation; and at no previous period are we to look for an accumulation of this kind sufficient for forming coal.

"If the reader has followed these hasty remarks, he may have gleaned enough to show him the utter futility of all attempts at mining for coal in the state of New York. The lower members of the formation, a sandstone and conglomerate, does, indeed, extend within the state, but it is below any part which contains coal. This conglomerate forms outlying masses on the tops of the highest hills in the southwestern counties; several of the localities present some interesting scenery, from the mass being divided into blocks of huge dimensions, between which are passages resembling streets, from which they have received the names of rock cities, and ruined cities. A few miles to the south of the state line, and upon this conglomerate rests the lowest coal bed, and to these sources we must eventually look for a supply of fuel."

TABULAR VIEW OF THE ROCKS OF NEW YORK, ARRANGED IN SYSTEMS, GROUPS, AND FORMATIONS.

Systems.	Groups.	Formations.
I. Post Tertiary	Alluvial. Diluvial. Clays and Sands.	
II. Old Red System.	Old Red Sandstone.	
III. New York Transition System.	Erie Group . . .	Chemung Sandstones and Flags. Ludlowville Shales.
	Helderberg Series	Helderberg Limestone. Schoharie Grit. Brown Argillaceous Sandstone. Encrinal Limestone. Oriskany Sandstone. Green Shaly Limestone. Pentamerus Limestone.

TABULAR VIEW—*continued.*

Systems.	Groups.	Formations.
III. New York Transition System—*continued.*	Ontario Group . .	Onondaga Salt and Gypseous Rocks. Limestone and Green Shales. Argillaceous Iron Ore. Soft red, green, and variegated, or Medina Sandstone.
	Champlain Group	Gray Sandstone and Conglomerate. Lorraine Shales and Roofing Slates. Utica Slate. Trenton Limestone. Birdseye. Chazy Limestone. Calciferous Sandrock. Potsdam Sandstone.
IV. Taghkanic System.	. . . .	Light green Slates, sometimes dark and plumbaginous. Gray and clouded Limestone. Brown Sandstone.
V. Gneiss System.	. . . .	Gneiss, Hornblende, and Mica Slate. Talcose Slate and Stealite.
VI. Superincumbent Rock.	. . . .	Greenstone, Trap. Porphyry.
VII. Unstratified Rocks.	. . . .	Granite. Hypersthene Rock. Primary Limestone. Serpentine. Magnetic Iron Ore.

The *transition system* includes all the rocks below the old red sandstone. They have been divided by geologists into four groups; the Champlain, the Ontario, the Helderberg, and the Erie.

The lowest layers of the *Champlain* group are composed of conglomerate sandstone of various colors from

brown to white. The limestones of this group furnish marble and lime of an excellent quality. The sandstone constitutes a durable building stone, and is also much used in the manufacture of glass, and sandpaper, and for polishing purposes. The upper portion furnishes stone suitable for grindstones. This group surrounds the primary, north of the Mohawk valley, extending into Jefferson county, south along both banks of the Hudson to the Highlands, easterly to the Taghanic range of mountains, and westerly through the Mohawk valley to Lake Ontario.

The *Ontario* group consists of three distinct portions: first, a marly sandstone, red, brown, green, and variegated —a large proportion of which is soft, and disintegrates rapidly on exposure to the weather; second, a series of soft green shales, succeeded by thin but numerous beds of argillaceous and siliceous limestones, alternating with each other and terminating in the Niagara limestone; and third, gypsum and salt rocks, constituting the Onondaga salt group. This group is bounded on the north by Lake Ontario, and extends easterly to Oswego county, where it meets the Champlain group—occupying a distinct belt, nearly equal in length to Lake Ontario, and about twenty miles in width. Its whole thickness does not exceed one thousand feet, of which the upper part, containing the plaster and salt, and beds of water-limestone, is most valuable.

The *Helderberg* series of rocks is most fully developed in Albany and Schoharie counties. It consists of a rough, gray, and somewhat irregular species of limestone, arranged in compact beds, above which occurs a dingy-green shaly limestone, with tough layers of a dark-green color. This is succeeded by a thin layer of the Oriskany sandstone—in some places a perfect hornstone—in others, containing lime. Next follows in the order of succession a thin mass of encrinal limestone, above which is a remark-

able brown shaly sandstone, with feathery appearances in the upper part, regarded by some as fucoidal impressions. The middle portion is a dark shaly sandstone, breaking into short pieces. Above this appears a calcareous sandstone, about four feet in thickness, and abounding in fossils. The Helderberg limestone, consisting of a gray, thick-bedded rock, the upper of a darker complexion than the lower, completes the series.

The *Erie* group is divisible into two portions—the lower consisting of shales upon thin beds of limestone, most of them quite decomposable; the upper of thin, even beds of gray sandstone, with intervening shales. The former have received the name of Ludlowville shales—the latter of Chemung group. They occupy a belt nearly twenty miles in width through the central portion of the state. The upper part of the group, consisting in part of a black shale and thin beds of limestone, but mostly of gray, thin-bedded sandstones, occupy the whole surface of the southern tier of counties, and form beds of passage into the old red sandstone.

The regular succession of these groups constitutes a remarkable feature in the geology of New York. They have a slight dip to the south and southwest; they are scarcely disturbed by uplifts, and succeed each other toward the south, until they are lost beneath the old red sandstone. The fossils of this group are very numerous and beautiful.

The *old red sandstone*, as a system, consists of gritty, micaceous shales, and thick and thin bedded micaceous sandstones, generally of a deep-red color, together with conglomerates, brown slaty grits, and soft red and green shales. Its area is confined chiefly to the Catskill mountains, terminating in the flagging-stones of the Chemung rock on the west. Around the base of these mountains are beds of passage from the transition to the

old red system. This system is finely developed in the ascent from the Catskill creek to the Mountain-House, in a series of terraces, exposing to view the outcropping edges as they succeed each other. It is here destitute of fossils; but the scales and bones of sauroid fish have occasionally been discovered. It extends westward nearly to the borders of the state, if we include in this formation the conglomerate, occupying some of the highest portions of Cattaraugus and Chautauque counties.

The class of rocks denominated *trap*, or *greenstone trap*, and *porphyry*, occurs either in the imposing form of columnar masses, like the Palisades, on the west bank of the Hudson, near New York, or in narrow veins or dikes with parallel sides, frequently projecting above the rock which they traverse. They are now universally regarded as of igneous origin, and as having either been injected in a fluid state into the fissures which they at present occupy, or as having been poured out upon the bottom of a sea, or upon the surface of other rocks, and there cooled under great pressure. Trap-dikes are extremely abundant in the northern section of the state: scarcely a mine of iron exists which is not traversed by them, frequently in such a manner as to derange the direction of the vein. Porphyry consists of a compact feldspar in which crystals are frequently found imbedded. This rock is the least developed of any of the geological formations of the state, and is found occupying a surface of a few miles only on Lake Champlain.

The clays and sands belonging to the formation denominated *post-tertiary*, skirt the shores of the St. Lawrence, Lake Champlain, and the Hudson, consisting of a stiff blue clay beneath, a yellowish-brown clay in the centre, and sand above. This clay, from the presence of marine shells, is regarded as an ancient marine deposite, and differs essentially from the clay of the alluvial formation. The

boulder formation, or *diluvial,* forms a coating of sand, gravel, and boulders, large and small—rounded by attrition, unequally distributed over the surface, apparently by the action of powerful currents of running water in a northerly and southerly direction, and in many places heaped up into round or conical hills. The *alluvial* formations consist of the gravel, sand, &c., now in process of aggregation by the various agencies of nature, comprising the beds accumulating at the mouths of rivers or in low grounds, and the matter washed up by the sea. Long island may be regarded as composed chiefly of materials thus collected by diluvial and alluvial agencies. Extensive alterations have taken place and are still in progress upon its shores, and within its bays and harbors, by the incessant inroads of the sea on the one hand, and the accumulation of marine deposites on the other. To the north of a range of hills running from east to west through the centre of the island, erratic rocks and boulders are found on the surface and imbedded in a series of strata forming the hills; while on the south they are of rare occurrence, the soil being mostly composed of fine pebbles, gravel, and sand.

"Excavations recently made in the navy-yard at Brooklyn," says Mr. Lyell, "have exposed the boulder formation to the depth of thirty feet; the lowest portion there seen consisting of red clay and loam, with boulders of trap and sandstone, is evidently the detritus of the new red sandstone formation of New Jersey. This mass in the sections where I observed it was about eighteen feet thick and rudely stratified. Above it lay an unstratified gray loam, partly of coarse and partly of fine materials, with boulders and angular blocks of gneiss, syenitic greenstone, and other crystalline rocks, dispersed at random through the loamy base, the whole being covered with loam eight feet thick. One angular block of gneiss which I measured

was thirteen feet long, by nine in breadth, and five feet high, but masses still larger have been met with and broken up by gunpowder. Mr. Redfield, who accompanied me to Brooklyn, suggested that the inferior red drift may have been accumulated first when the red sandstone of the neighboring country was denuded; and that afterward, when the land was submerged to a greater depth, and when the gneiss and hypogene mountains of the highlands alone protruded above the waters, the upper drift, with its erratics may have been thrown down. I am well disposed to adopt this view, because it coincides with conclusions to which I was led by independent evidence, after examining the districts around Lakes Erie and Ontario, viz., that the drift was deposited during the successive submergence of a region which had been previously elevated and denuded, and which had already acquired its present leading geographical features and superficial configuration. At South Brooklyn I saw a fine example of stratified drift, consisting of beds of clay, sand, and gravel, which were contorted and folded, as if by violent lateral pressure, while beds below, of similar composition, and equally flexible, remained horizontal. These appearances, which exactly agree with those seen in the drift of Scotland or the north of Europe, generally accord well with the theory which attributes the pressure to the standing of ice islands, which, when they run aground, are known to push before them large mounds of shingle and sand, and must often alter greatly the arrangement of strata forming the upper part of shoals, or mud-banks and sand-banks in the sea, while the inferior portions of the same remain unmoved.

"Mr. Mather, in his report on the geology of this portion of New York, states an interesting fact in regard to the arrangement of the boulder formation on Long island, which, as before mentioned, extends for about one hundred and thirty miles east and west. At its eastern ex-

tremity the boulders are of such kinds of granite, gneiss, mica-slate, greenstone, and syenite, as may have come across the sound from parts of Rhode Island immediately to the north. Further westward, opposite the mouth of the Connecticut river, they are of such varieties of gneiss and hornblende-slate as correspond with the rocks of the region through which that river passes. Still further west, or opposite New Haven, they consist of red sandstone, and conglomerate, and the trap of that country; and lastly at the western end, adjoining the city of New York, we find serpentine, red sandstone, and various granitic and crystalline rocks, which have come from the district lying immediately to the north. This distribution of the travelled fragments will remind every geologist of the manner in which distinct sets of erratics are lodged on the Swiss Jura—each set, whether of granite, marble, or gneiss, answering in composition to those parts of the Alps which are nearest and immediately opposite, as if they had crossed the great valley of Switzerland, more than fifty miles broad, in a direction at right angles to its length. The sound, which separates Long island from the main land, is from five to twenty-five miles broad. The fragments have doubtless been transported by ice; but we must suppose them to have been floated by ice-islands in the sea, as there are no high mountains in this part of North America from which glaciers can have descended after the continent had acquired its present shape and altitude."

The island on which the city of New York is situated is composed of the rock termed gneiss; and this formation extends northerly for a considerable distance on the west bank of the Hudson river, developing itself prominently in the cliffs exposed to observation on the margin of this noble stream. At Hoboken, cliffs are seen of serpentine, a rock which appears to be subordinate to the gneiss. These formations, as well as the syenite of Staten

island, correspond very closely with European rocks of the same order.

Mr. Lyell, in his "Travels in North America," has the following observations, in reference as well to the general appearance of the formations on this continent, as to the particular strata found in New York: "In the course of this short tour (from Albany to Niagara falls), I became convinced that we must turn to the New World, if we wish to see in perfection the oldest monuments of the earth's history, so far at least as relates to its earliest inhabitants. Certainly in no other country are these ancient strata developed on a grander scale, or more plentifully charged with fossils; and as they are nearly horizontal, the order of their relative position is always clear and unequivocal. They exhibit, moreover, in their range from the Hudson river to the Niagara, some fine examples of the gradual manner in which certain sets of strata thin out when followed for hundreds of miles, while others, previously wanting, become intercalated in the series. Thus, for example, some of the limestones which are several hundred feet thick in the Helderberg hills, near Albany, are scarcely forty feet thick in the Niagara district; and, on the other hand, the rocks over which the cataract of Niagara is precipitated dwindle away to such insignificant dimensions when followed eastward to the hills southwest of Albany, that their place in the series there can scarcely be recognised. Another interesting fact may be noticed as the result even of a cursory survey of the fossils of these North American rocks, namely, that while some of the species agree, the majority of them are not identical with those found in strata which are their equivalents in age and position on the other side of the Atlantic."

Professor Hall, in reference to the constant and rapid process by which rivers are excavating for themselves new channels, and producing in some instances, and in oth-

ers deepening modern valleys, has the following observations:—

"Perhaps there is not a more stupendous example of this kind than that furnished by the channel of the Niagara river, in its passage from the falls to Lewiston. The banks below the falls are one hundred and sixty feet high, and at Lewiston about three hundred: and to this we have to add the depth of the river. The whole of this gorge is excavated from solid rock, mostly limestone and sandstone. There is no evidence of an ancient valley, and we are compelled to believe that the stream has been the chief, if not the only agent, in the production of its channel. In order to conceive of a stream like that of the present cataract having worn this channel, it requires that we extend our ideas of the past to an immense period. If we compare the present rate of recession in the falls with the past, it must have required many thousand years to produce the gorge of seven miles, with a depth of from at least three hundred to six hundred feet. In some instances, however, operations of this kind go on more rapidly than we usually suppose, and a deep channel may be worn in solid strata in a comparatively short time. The Genesee river at Portage has excavated its channel to the depth of three hundred and fifty feet in the rocky strata, and passes over them by successive falls in the space of about one mile. The period when this began is, of course, beyond historical record, but changes are still operating which lead us to believe that a few thousand years may produce phenomena which would appear impossible when we look upon the quiet and almost imperceptible operations of nature around us. At this place the greatest changes appear at the lower falls, rendering it almost improper to say that there is a *fall* of water, though the table or platform over which the water was once precipitated still remains, and in high freshets some portion still flows in that direction. This

channel is worn to the depth of more than fifty feet in its deepest part, gradually receding till it reaches the level of the river-channel above, the stream flowing through it in a violent rapid. In the course of this operation a projecting mass of rock remained, which was subsequently separated from the bank, and now stands an isolated conical mound. All this has been accomplished within the memory of the present generation; the materials thus eroded from the solid strata have found their way down the stream, the larger fragments soon resting, while the finer have been deposited upon the Genesee flats and transported to Lake Ontario. After noticing these facts, the observer can not fail to perceive that the fine sediment forming the deep soil of the Genesee valley below Mount Morris is the ruins of some of the older rocks; and if he compares the effects of the Genesee, in the case cited, he will conclude that the entire gorge between Portage and Mount Morris has been excavated in the same manner, and that its materials now fill the valley before mentioned. He will have less hesitation on this subject if he examines the soil about the opening of the gorge at Mount Morris, where fragments of the rock appear of the same kinds as those forming the cliffs along the river further south. He has only to apply the same principle, and to conceive of similar operations over the whole surface, and he can understand how the deep alluvium has been produced by the excavation of the broad and deep valleys which everywhere indent the surface. He may not be able to see, it is true, the causes now operating which would produce such changes, but he can reason from the smaller to the greater with unerring certainty. If the rich bottoms of some of the ravines are excavated, we find the fragments of rocks piled up in confusion, and above them a rich fine soil—while a small stream flows through its centre, depositing in miniature similar accumulations of fragments. If we can

conceive of a powerful stream flowing in the same channels, we have all the requisites for such a production. We often find very insignificant streams flowing in broad and deep channels, presenting waterfalls of astonishing height, when we consider that the whole has been excavated from solid rock.

"The operations of water and air, either in the simple operation of wearing or of decomposing, or in the effect of freezing, are producing constant changes, not only in river-channels and in ravines, but over the whole surface; not on rocky masses alone, but also on the fragments and pebbles imbedded in the soil. By this means new materials are constantly furnished to supply the waste produced by the cultivation of the soil. The decomposition of granite furnishes potash and other earths or alkalies; the limestone lime and magnesia, and some of the other rocks furnish salts of these earths or alkalies. When we regard the great extent of some of our limestone formations which contain iron pyrites and magnesia, and which on decomposition afford sulphate of magnesia, we know that an immense quantity of this soluble salt is afforded to the soil, and which, by other decompositions, may be afforded to the grains in the form of a phosphate of magnesia. The soft shales of the Niagara group and the Clinton group yield on decomposition soluble salts of magnesia and lime, of the most vital importance in the production of crops; and in the natural operations we find the result to be a most fertile soil. The farmer has only to imitate nature in this respect, and place these shales in favorable situations, to produce the same effect, and to give him a constantly fertilizing agent for his soils. The marls of the Onondaga salt-group, which are shown to range through the state from east to west, are of similar character, and can be most advantageously employed, more particularly on sandy soils. There are nowhere better wheat-producing

soils than the oak openings on the Onondaga salt formation. Again, the shales of the Hamilton group, further south, present the same character, and their decomposition produces the fertile soils of Livingston and Genesee counties. I need not at this time dwell longer upon these points. Every operation which changes in any manner the condition of a pebble or a rock, is of the most vital interest to the farmer; and though the soil produces, and the rocks, decomposing, supply the required materials to the soil, without his knowledge or consent, still, will any one assert that the operations of such laws are not of sufficient importance to be understood, or that the farmer has no interest in the influence of physical and chymical causes? On the other hand, we clearly know that it is by a knowledge of these laws that he will be enabled always to continue his land in a fertile state, and to increase rather than diminish the productions of his soil, and, in fine, to become what the Creator intended, the lord of the earth. From the mineral nature of the various rocks, the character of the soil derived from their decomposition, and their capabilities of improvement, the farmer will be made aware that about him, on every side, and near him, are beautiful scenes, where he may refresh himself and his family after their days of exposure and toil; where at the same time he may acquire instruction from the myriads of organic remains imbedded in the rocky strata, showing him a prior condition of this earth, when other existences, with other wants, flourished over the wide extent now covered with the fertile soil which yields to man his sustenance. In every rock, and in the loose stones turned up by his plough, he may find the same evidences of these former creations. And if he can not, from such knowledge, learn how to improve his farm, he can at least see that the destruction of these fossil shells has given him lime to enrich his soil, and that the animal matter, in some other

combination, is doing him the same service. It is true they exist, and accomplish all this, whether he knows it or not, and the fact is still the same: but does the intelligent farmer rest contented, while ignorant of the causes of all these things? And even if ideas can not be turned to dollars, he must feel that he has a soul to be satisfied—a spark of that Divine Intelligence which has created man, and given him this earth as his home. Our farmers desire to have their children grow up in a knowledge of what is around them: and if knowledge be power, we need not ask for its direct or immediate application, but rest assured that it will give us the power of doing good, and of improving in virtue and increasing in happiness."

PART V.

PRACTICAL RESULTS OF GEOLOGICAL SCIENCE.

To an observer favorably situated for the contemplation of the various aspects of the present, viewed in the light of the past and of the probable future, no subject can be of greater interest than the progressive advancement of physical science. The successive stages of improvement through which the civilized portions of mankind have passed, by a slow and gradual transition from the lowest point of intellectual attainment, to the most commanding heights of science and of mental elevation; the continued expansion of knowledge in every direction, consequent upon the benignant influences of an advancing civilization, resting upon the strong foundations of an enlightened Christianity, and deriving its chief element of progression from the prevalence of general peace and a mutual interchange of kindness and good offices, among the several nations and individuals participating in its benefits; and the systematic development of those fundamental principles which lead to an unlimited series of discovery and successive generalizations in the vast domains of scientific inquiry; these topics afford an inexhaustible field for observation, for reflection, and for study. If we cast back our eyes to the earliest records of the race, we shall discover little else than the prevalence of untamed propensities seeking their gratification in profound ignorance of the laws of being; and in the midst of the most civilized and flourishing communities which

have since arisen, a large proportion have at all times been found immersed in the deepest and most chaotic mental gloom; the slaves and victims of the most debasing passions—ignorant alike of their origin, nature, and destination—seeking only the opportunities and the means of accomplishing the imperious requirements of their animal being. Regarded either in a physical, intellectual, or moral point of view, the difference between the roving tribes of the wilderness or the desert, at the earliest period of which we have any traces, and at the present day, is scarcely perceptible; and the difference between either of these classes and the Russian serf, the European boor, the degraded and stupified inhabitant of the colliery, the mine, the galleys, or the hulks, and of the thousands in our great capitals, wholly dependent upon their physical energies for a precarious and miserable support from day to day, is one of degree only, and not of kind. In exact proportion as the intellectual and moral faculties have been developed and brought into action, and to the diffusion and extent of such development and activity, has been, at all times and under all circumstances, the progress of civilization and social refinement; bringing in its train all the arts and sciences, the comforts and enjoyments of life; affording security to the property and the person; widening the sphere of profitable exertion, and affording increased facilities for the cultivation of all those virtues and graces which adorn and distinguish humanity.

The establishment and regulation of social intercourse, the organization of governments and institutions, civil and religious, the enactment of laws for the protection of all the varied interests to which society gives birth, the accumulation, distribution, and enjoyment of wealth, the attainment of rank, station, influence, and power, and eventually the systematic direction of a portion of the

time, intellect, and enterprise of the community, to the advancement of science and the moral and social elevation of all, are uniformly, or with rare exceptions, the natural and successive fruits of the introduction and diffusion of knowledge, and of the elements of Christian civilization.

The "middle wall of partition," which ignorance and fanaticism have for so long a period succeeded in maintaining between the legitimate results of a sound induction of physical facts and phenomena, and the religion of the Bible—the unerring standard of our faith and duty, has, we may reasonably be permitted to hope, been effectually demolished; and in proportion to the advancement of knowledge, science, in all its diversified departments, is now universally recognised as the efficient handmaid and faithful auxiliary of true Christianity. Truth is "one and indivisible," whether it emanates directly from its great original, or unfolds itself gradually and slowly to the perception of its votaries in the vast laboratory of nature and of art. The time has gone by—never we trust to return—when the erring and fallible *interpretations* by individuals, synods, or councils, of the revealed wisdom of the omniscient; interpretations imbued with the manifold imperfections necessarily incident to human knowledge, even in its highest manifestations, were deemed conclusive upon every department not only of faith and practice, but of discovery and scientific research; not only in the moral and intellectual, but the physical and material world; in the universe as well of matter, as of mind. An expansive and searching, and at the same time, a reverential and confiding philosophy has arisen among men, which "looks *through Nature*, up to Nature's God;" which, recognising in all the innumerable developments of the creative force, one all-powerful, all-pervading hand, operating in accordance with certain all-com-

prehending and invariable laws, is under no apprehension in its widest inductions and most expansive generalizations, of coming in collision with contradictory or repugnant truths deriving their origin and vitality from the same perfect sources. Hence the progress of scientific inquiry is no longer hampered and restricted, as formerly, by limitations originating in ignorance of the fundamental nature of truth and knowledge, and kept alive by superstition and bigotry, excited and cherished by sacerdotal intolerance and blindness. As the unerring rule of faith and guide of life; as the harbinger and exponent of immortality; as the repository of that wisdom which alone can direct the uncertain footsteps of humanity amid the labyrinthine mazes of time and chance, the BIBLE asserts an authority final and conclusive: and whatever contradicts its teaching in these great departments of religion, morality, and human ethics, is necessarily false and erroneous. But in communicating these great lessons of faith and duty to a long series of generations preceding the very dawn of scientific investigation, incidental allusions to the various phenomena of the material universe, the "stars in their courses," the sun, the moon, the planets, our earth itself and its properties, and the innumerable and infinitely varying manifestations of light, heat, vapor, atmospherical changes and elemental warfare, language in all respects corresponding to the universal conceptions of the race, adapted to their comprehension, and in consonance with their attainments, was natural and indispensable. Nor was this necessary recognition of erroneous conceptions of physical truths, which thus obviously pervades the records of inspiration, in any respect designed to preclude the most thorough and extensive investigation of these subjects, without regard to the results of such investigation upon pre-existing beliefs. In exploring, therefore, the domains of science, we submit ourselves

unreservedly and fearlessly to the guidance of those established principles of analysis and induction which observation and experience have united in commending to our use; convinced that whatever advances have been or may be made in this direction, can never be in *contradiction* to the living oracles of truth, however far they may *transcend* those imperfect conceptions of its details, which prevailed in the infancy of the race.

In no department of scientific investigation are these principles more constantly and systematically to be kept in view, than in that of GEOLOGY. Their application to the kindred science of astronomy, although slowly and reluctantly conceded during the progress of successive centuries of comparative darkness and ignorance, is now universally recognised; and the obvious discrepancy between the legitimate deductions of science, in this important department of human knowledge, established and confirmed by the observations and reasonings of an unimpeachable philosophy, and the literal import of those scriptural passages which incidentally refer to the various cosmical phenomena, neither disturbs our confidence in the value of those magnificent results which modern discovery has brought to light, nor undermines our faith in the absolute verity and conclusiveness of revelation. We see at once the utter absurdity of looking for an authoritative exposition of the vast field of physical science, in an age and among a people entirely unfitted, in the order of Providence for its reception; at a period when scarcely a perceptible advance had been made in the knowledge of the material universe; and to individuals and communities whom nothing short of a miraculous development and expansion of the higher intellectual faculties, could have adequately prepared for the annunciation of its comprehensive principles. So with reference to the modern science of geology, it becomes us to bear in mind that it

is only since, or immediately preceding the commencement of the present century, that a clear conception of its fundamental truths, and a methodical and intelligent arrangement of its grand results, have been attained; that for these we have been indebted to the profound researches and comprehensive inductions of the most powerful and enlightened minds of an age remarkable for intellectual advancement and scientific development; that no portion of these truths, no combination of these results, conflict with the testimony of those ancient records of creation which we are rightly accustomed to regard as authentic, so far as that testimony has any bearing either upon the remote original, of the universe itself, its author and pervading spirit, or the period during which man and his works have had an existence upon our planet; and that it is only, when the brief and obscure intimations of the sacred writers in reference to the *particular period* when the universe itself, together with the physical materials of which our earth is composed, were originally produced, are regarded as authoritatively maintaining a doctrine at variance with the indubitable results of scientific research, that any discrepancy *appears* to exist between reason and revelation.

In the simple but sublime annals of creation which the inspired legislator of the Hebrews was commissioned to unfold, the unity, omnipotence, and omniscience of the Deity, and the construction of the vast fabric of the universe, "in the beginning," by his almighty fiat, were the fundamental propositions to be impressed upon mankind in the earliest period of its history, and transmitted from age to age down the current of time. The process employed by the Divine architect, in moulding and shaping the "forms of things;" the times during which the various portions of this great work were successively or simultaneously elaborated; the agencies brought to bear

upon their periodic or contemporaneous development; or the cyclical revolutions of those vast and indefinite periods which so far as we can perceive must have preceded their consummation in the appearance of man; these were matters as far beyond the comprehension of the nomadic people to whom the revelation was originally made and for whom it was primarily and chiefly designed, as they were unconnected with its main scope, and obvious purport. We are, therefore, at full liberty to accept the deductions of modern science, in this interesting field of knowledge, however they may transcend our previous conceptions of the import of scriptural phraseology; nor in the prosecution of our researches in this direction is it at all material that we should be able to bring into apparent concord, by means of a forced and unnatural interpretation of plain and obvious expressions, the numerous incidental or narrative allusions made to this subject in the sacred volume, and the results of scientific analysis and philosophical induction. Neither the interests of religion nor of science are likely to be subserved by such a process; and a sacred regard to the cause of truth, and the promotion and diffusion of sound knowledge, demands the adoption of a higher and nobler standard as well of moral and religious as of physical belief.

The principles by which our faith—our convictions of moral and religious duty—our estimate of the relations in which we stand to each other, and to our Creator—and our conceptions of the illimitable future—are to be formed and guided, constitute a separate and distinct department of mental inquiry, the elements of which lie deeply imbedded in our moral and religious nature, and are "brought to light," by the inspired teachings of revelation. These principles were coeval with the creation of the human race; and equally applicable in the earliest as in the latest stages of human advancement. Their obli-

gations and requirements were as imperative and binding upon man in the infancy of his being, as in its most mature development; and consequently in some form or other, they have been communicated to him in all periods and under all circumstances of his existence, with sufficient clearness, precision, and certainty, to enable him to accomplish the great purposes of his immortal nature. On the other hand, those great discoveries and results in the various arts and sciences with which we are now, or may easily become so familiar, that they cease to be regarded with wonder and astonishment, were, a few centuries since, either wholly unknown, or confined within the knowledge of a few master-spirits, to whose minds they were slowly and gradually unfolded, as the recompense and result of toilsome and painful years of deep thought and comprehensive research. One after another they were matured and unfolded; subjected to the severe crucible of contemporaneous skepticism; modified and expanded to conform to the increasing progress of knowledge in other departments; and ultimately incorporated into the circle of established truths, accessible to all, and subject to all those uses in the advancement of science, which future ages and a higher civilization may require. Whatever may be the problems which remain to be solved, in the application of existing knowledge to the present and future exigencies of the race, the extent and certainty of that knowledge can admit of no doubt; and without being required to retrace any of the steps by which it was originally discovered, or to recombine any of the elements of which it has been composed, we have only to make such use of it as may best subserve the purposes we have in view, confidently relying upon the genuineness, firmness, and durability, of the materials thus placed at our command.

"Why should we hesitate," observes Professor Hitch-

cock, "to admit the existence of our globe through periods as long as geological researches require, since the sacred word does not declare the *time* of its original creation; and since such a view of its antiquity enlarges our ideas of the operations of the Deity, in respect to *duration*, as much as astronomy does in regard to *space?* Instead of bringing us into collision with Moses, it seems to me that geology furnishes us with some of the grandest conceptions of the Divine attributes and plans to be found in the whole circle of human knowledge."—"If I understand geology aright," he again observes, "so far from teaching the eternity of the world, it proves more directly than any other science can, that its revolutions and races of inhabitants had a commencement; and that it contains within itself the chymical energies, which need only to be set at liberty by the will of their Creator, to accomplish its destruction. Because this science teaches that the revolutions of nature have occupied immense periods of time, it does not, therefore, teach that they form an eternal series. It only enlarges our conceptions of the Deity; and when men shall cease to regard geology with jealousy and narrow-minded prejudices, they will find that it opens fields of research and contemplation as wide and as grand as astronomy itself."

Having thus disposed of this important preliminary point, by reference to a process of reasoning which, when expanded and analyzed from the various points of view of different observers, has hitherto, with rare and unimportant exceptions, proved satisfactory and conclusive to the most strictly conscientious and religious minds in both hemispheres, and removed from the path of scientific inquiry every obstacle growing out of an apparent conflict with revealed truth, we shall proceed, very briefly to inquire into the practical benefits which may be likely to accrue, from the prosecution of the modern science of

geology, as illustrated and expounded by its ablest commentators. Knowledge, of every description, is, undoubtedly, its own "exceeding great reward;" and there is a pleasure and a satisfaction in penetrating to the deep and exhaustless fountains of science; in accumulating, arranging, classifying, and appropriating facts in every department of the world of matter and of mind; in the establishment of fundamental and comprehensive principles, underlying the vast arcana of the universe, pervading all space and existing in all time; in ascending from effects to causes; and uniting in one complex but harmonious whole, the infinite variety of things which everywhere surrounds us; and this, wholly irrespective of any practical results—any direct application to the ordinary purposes of life. "The question 'cui bono?' to what practical end and advantage do your researches tend," observes Sir John Herschel, in his Discourse on the Study of Natural Philosophy, "is one which the speculative philosopher, who loves knowledge for its own sake, and enjoys, as a rational being should enjoy, the mere contemplation of harmonious and mutually dependent truths, can seldom hear without a sense of humiliation. He feels that there is a lofty and disinterested pleasure in his speculations, which ought to exempt them from such questioning: communicating, as they do to his own mind the purest happiness, after the exercise of the benevolent and moral feelings, of which human nature is susceptible, and tending to the injury of no one, he might surely allege this as a sufficient and direct reply to those who, having themselves little capacity, and less relish for intellectual pursuits, are constantly repeating upon him this inquiry."

"It is hardly possible," observes Professor Hitchcock, in an address delivered by him before the American Association of Naturalists and Geologists, at their first meeting,

at Philadelphia, "to place the geologist in any spot on the globe, where he does not witness around him the marks of mighty agencies and revolutions that are unheeded by the common mind, but which furnish him with a rich fund for reflection. Henceforth he possesses a source of gratification, of which all the fluctuations and calamities of life can not deprive him. Other sources of happiness, as circumstances change and age advances, will pass away. But a genuine attachment to nature, clinging to the heart, will buoy it up, when the powers begin to fail, and the floods of affliction to roll over us; and like the volcano, surrounded by polar snows, the flame will seem more bright and beautiful, amid the frosts of age."

But, however exalted and even indispensable to the progressive development of the various useful arts, may be this abstract devotedness to the acquisition of knowledge for its own sake, in the minds of those to whom, in the dispensations of Providence, it is given to become the discoverers, the pioneers, the apostles—perhaps the martyrs—of science, the essential value of the highest intellectual gifts and attainments, consists in the ability which they confer to add to the existing stores of available power—in their practical adaptation to the physical, intellectual, and moral wants of the race.

To Archimedes, Euclid, Galileo, Stevinus, Newton, and others of kindred genius, it may be permitted to retire within the inner sanctuary of the god-like mind for the elaboration from the purest fabrics of the intellect, of those universal principles of matter—those laws of the material universe—which exist and are true at all times, in all places, and under all circumstances; which are independent of the agency of human effort or wisdom; and are connected with the fleeting interests of time and sense and humanity, in so far only as they are capable of

being rendered subservient to the purposes of the race by those special adaptations of unbending principles to passing events, which the enlightened intellect is from time to time enabled to compass. But of those to whom it is given only to retrace the steps of these mighty explorers in the domain of the pure reason; to repeat the experiments and recombine the materials; and confirm the results of these inspired investigators into "the life of things;" the great and beneficent purposes of intellectual, social, and moral existence imperatively requires, that practical adaptation of means to ends, and those extended and productive uses, which have a tendency to the progressive advancement of true civilization in all its varied and comprehensive aspects. Had our illustrious countryman, Bowditch, simply contented himself with those patient, persevering, and exhausting labors which were necessary to a full comprehension and an adequate appreciation of the *Principia* of Newton, and the "*Mecanique Celeste*," of La Place; had he rested satisfied with combining in one masterly view those magnificent processes of geometrical investigation which, thus brought together, embraced all the known results of gravity upon the bodies of which our solar system not only, but all the systems which pervade the immensity of space, are composed, he would, indeed, have accomplished an herculean task, and his name would have been transmitted to the remotest posterity, in conjunction with those of the great masters whose ineffaceable footsteps he had so faithfully traced, compared and connected into one great highway of scientific investigation. But his memory rests on a still firmer and more durable basis, in the practical application which he gave of those immense combinations of physical science, to the purposes of marine navigation; enabling the humblest intellect to direct the pathway of the stateliest vessel through the expanse of the trackless

ocean, with that unerring certainty and confidence which an accurate and familiar acquaintance with the fundamental principles of astronomical and mathematical science alone could otherwise have given. In like manner, the comparative exemption which we enjoy from the destructive power of the electric fluid, attests the eminently practical nature of those investigations of the laws of atmospherical phenomena, which FRANKLIN so successfully and yet so laboriously prosecuted; and the invaluable because inappreciable preservation of human life in the perilous and mephitic recesses of the mineral world, by the use of the safety-lamp, has amply rewarded the consecration of the time and genius of Sir HUMPHREY DAVY, to the science which may be said to owe its birth to his discriminating and comprehensive mind.

What, then, have the discoveries and researches of the eminent individuals who have devoted themselves to the elucidation of the principles of geological science, effected, or what may they reasonably be expected to effect, in the advancement of that career of practical civilization which constitutes the distinctive characteristic of the present age? The inquiry is both pertinent and important; and unless a satisfactory and convincing answer can be given, we shall look in vain for that general appreciation and adoption of the truths we have to offer which can alone render them subservient to the great interests of humanity.

The striking fact, however, that these truths, the reasonings and inductions from which they flow, the extraordinary and resistless testimony by which they are supported, and the important deductions to which they lead, *have* not only been widely appreciated and adopted, but espoused with an animation, an enthusiasm, and an interest more general and pervading even than those which lend so powerful an attraction to the kindred

sciences of astronomy and chymistry, goes far, of itself to rescue our investigations in this department of knowledge, from the imputation of barrenness or want of practical adaptation to the substantial purposes of life. There must be something more than the gratification of an idle curiosity, or the pleasure arising from the solution of an interesting but abstract problem of history, of physiology, or of dynamical forces operating upon or beneath the surface of the earth, to enlist the best energies of the ablest and most enlightened philosophers of Europe and America, during a period of more than half a century; to awaken the exertions and secure the active co-operation of a succession of finished scholars and accomplished cultivators of science, in an age distinguished perhaps above all others for its searching discrimination between the *real* and the *ideal*, and for its cautious skepticism in the recognition of new elements of thought and of action; and what is still more remarkable and well nigh decisive of the point under consideration, to excite the deepest interest, and call forth the most unaffected enthusiasm, in the breasts of thousands, in every section of the civilized world, whose situation and pursuits in life have debarred from those investigations which could enable them to pronounce a scientific judgment upon the intrinsic value of the phenomena thus brought under review. Let us, then, briefly recapitulate some of the elements which compose the modern science of geology, with a view to ascertain in what respect it may be supposed to have a practical bearing upon the pervading interests of every civilized community.

And first, it unfolds the gradual adaptation of the surface of the earth, to its successive races of inhabitants, carrying us back to a period long anterior to the existence of living beings, when the primordial elements of matter were arranging themselves, under

the guiding hand of the Creator, from a chaotic aggregation of intensely heated fluids, into a consolidated mass of granitic rocks; swayed hither and thither by the gigantic force of subterranean heat seeking an outlet for its pent-up vapors; here uplifted and elevated into the adamantine nucleus of a mountain range; there depressed, contorted, bent, doubled upon itself and ultimately resting, variously inclined, as the expansive and uplifting forces gradually ceased or changed their direction; a state of things obviously irreconcilable with animal or vegetable life: the infancy of our planet; but an infancy stretching far back beyond our utmost conceptions of time —when time, indeed, was not—for there was no living being to mark its divisions, or take cognizance of its existence.

Next we are called upon to mark the operation and effects of those elements which, during this long and fearful period of violent action and reaction, had surrounded the new-formed earth—composing a dense and mephitic atmosphere—originating by its inherent and variously-compounded forces a vast superincumbent ocean, and by its necessary tendency to equilibrium above, around, and below, giving birth to those winds, tides, and oceanic currents, which first disintegrated and decomposed the highest and most exposed caps of the inclined rocks, and then carried down their fragmentary particles, by streams and rivers wherever a channel had been worn, to the ocean, over whose vast bed they were distributed for a succession of ages—hardened and consolidated by superincumbent pressure and subjacent heat—and again, in the progress of the great dial-plate of eternity, elevated above the surface of the waters by the same powerful and restless forces by which they were originally formed; again and again to undergo a similar process in the vast laboratory of creative energy.

Periods of intense and uninterrupted volcanic action

were succeeded by long intervals of repose and tranquillity, during which the bed of the sea was overspread with the constantly-accumulating *debris* of the rocks on the earth's surface; and while the layers first deposited were undergoing the process of consolidation to which we have above referred, the more recent beds became the receptacle of the primeval possessors of animal life, the *molluscs*, the *fuci*, the *polyparia*, *crustacea*, *crinoidea*, including *trilobites*, *radiata*, and various species of *fishes*. Then appeared also the first traces of vegetable life, oceanic and terrestrial; sea-weeds and cryptogamous plants, flowerless and naked; coral-reefs, elaborated during countless ages by myriads of the radiated *polyparia*, gradually emerged from the depths of the ocean, or were elevated by the action of subterranean forces, to be in their turn decomposed and redeposited as a distinct and clearly-marked stratum, again to reappear upon the surface in the revolution of succeeding ages.

We next reach, in the ascending series of geological phenomena, the *carboniferous* era; a period abounding in interest, and fertile in events, destined to exert an auspicious influence upon the future physical welfare of the race. Extensive regions of the earth, surrounded by a vast expanse of ocean, were clothed with a vegetation, rank and luxuriant in the extreme, consisting of mighty primeval forests of palms, arborescent ferns, and gigantic trees, resembling in structure the modern *equisetæ;* while the waters continued to abound in mollusca, radiata, crustacea, and fish. The waste and decaying remains of these immense forests of a tropical climate, were annually floated down by rivers and currents to the ocean, and there deposited in solid beds, interstratified by and alternating with the successive and simultaneous deposites of mineral origin, to reappear after the revolution of innumerable centuries, in a consolidated and metamor-

phosed form, in inexhaustible quantities, as coal. At this period, there is every reason to believe not only that a tropical climate pervaded the greater portion of the surface of the earth, the effect, in part, perhaps of the preponderating prevalence of immense bodies of water in every direction, but that the earth itself was one vast archipelago; an ocean studded with uninhabited islands —some of greater and some of less dimensions, but nowhere spreading out into those broad continents which now present themselves to the eye. The remains of these scattered islands are now visible and may be measured by the coal-bearing strata. In our own hemisphere the geologist can point with demonstrable certainty to the location and prominent boundaries of the terrestrial domain —where now the mighty Atlantic rolls its waves, extending to the eastern declivity of the existing Appalachian chain of mountains, beyond which the primeval ocean became the grand reservoir of the ample materials for the subsistence and preservation of a race whose being yet lay concealed in the counsels of Omnipotence. Here were deposited during a countless succession of years, perhaps of ages, from the annually-recurring waste of the luxuriant and gigantic forests which overspread the adjacent continent, the rich stores of vegetable matter, which, fused, combined, and consolidated in nature's great laboratory, now compose the inexhaustible coalfields of the south and west. By a similar process, the immense coal districts of the island of Great Britain were elaborated; and it is only in the formations of this early period in the annals of creative energy; only in regions where the industry and art of man, aided by the developments of nature can penetrate to these lower chambers of the mighty frame-work of the globe; that this important portion of its mineral treasures will yield itself to his demands. Rich, varied, and inexhaustible, as are the

provisions thus stored up for the high uses of a progressive civilization, they must be sought for only in that specific repository where the Almighty Architect, myriads of ages before man existed, deposited, arranged, and dedicated them to the purposes of his infinite providence.

Over them, the varied creations of ages upon ages have successively been piled: tremendous earthquakes and cataclysms have elevated, distorted, shaken, and riven their consolidated masses; volcanic eruptions have pierced through their adamantine bulk, and left their fiery traces deeply engraven in seams of mineral wealth upon their huge surface; and in the alternations of those vast elemental forces which have thus operated with such gigantic power, over a period which the imagination seeks in vain to compass or comprehend, a surface of extent sufficient to embrace an area adequate to all the purposes of man for countless generations, has been elevated to a point whence he may command its immense resources, and apply its exhaustless treasures to the supply of his wants, in whatsoever direction the majestic march of civilization may require their agency.

Surely, if geology had done no more than to assure us of this important fact; if its sole claim to our attention and regard consisted in the discovery and identification of the *coal-bearing strata*, throughout the earth, and in the irrefragable demonstration of those conditions under which, alone, we may be assured of its existence and extent; it would have established its title to an honorable name and an exalted place among those sciences most eminent for their practical utility and beneficent results. What treasuries of wealth, what painful expenditure of labor, what vast energies of skill and enterprise, have in all ages been fruitlessly expended in the search for this invaluable mineral in situations where, in the light of geological science, we now know, its occurrence was

physically impossible? And is it not much, that an infallible and unerring direction has thus been given to all our future exertions in this great field of human enterprise and research?

"There is one thing," says Professor HALL, in a valuable paper communicated by him to the New York State Agricultural Society, "to be constantly borne in mind, viz., that order is the first law of nature; that the materials forming the solid crust of our globe are arranged in a definite sequence; and that this arrangement is *always and everywhere the same*. Such valuable substances, therefore, as we seek, are not the result of accident and chance; but the product of fixed and unerring laws, which govern in all places, and all periods of the earth's history. Coal is not to be sought indiscriminately in all rocky strata, neither, indeed, in all those where we find indications of its existence. There has been one period in the geological history of our continent when this material was produced in incalculable quantities and spread over wide areas. It is true, that, at some subsequent periods, there have been partial depositions of this mineral; but it must be totally useless to search for it in rocks formed at a period previous to that denominated the coal formations. Such is equally true of all the other useful and valuable productions."

Pausing at the period of the earth's history which we have now reached, we distinctly perceive the strongly-marked indications of two separate periods of repose, and two of disturbance; during the former of which, the spoils of the existing land, the disintegrated fragments of the different species of rocks, the decayed and decaying vegetation of continents bending under the weight of mighty forests, were annually carried down to the surrounding ocean, and piled upon its rocky bed where, in the long revolutions of ages, it was pressed and consoli-

dated in every direction, and by various agencies metamorphosed into an immense mass of mineral substances, preparatory to its reappearance on the great theatre of terrestrial creation. Then came into action the tremendous forces of the subterranean elements, upheaving the superincumbent masses; forcing a passage through the solid rocks for torrents of intensely-heated lava; here scooping out new beds for the sea, and there throwing up high above the surface of the former ocean, the compact materials accumulated and consolidated beneath its waves, piling them in confused, inclined, and contorted shapes wherever the resistless direction of these mighty energies pointed, and swallowing up and completely exterminating whole races of organic life. It is to be observed, however, that these powerful and destructive agencies of long-continued violence, extensively as they predominated, were by no means universal; that they were circumscribed by large areas over which no indications of unusual disturbance are perceptible; and succeeded by long periods of tranquillity and repose, the appearance of new types of organific life, and the predominance of a new order of terrestrial phenomena.

Next in order we approach the *new red sandstone system*, a deposite composed chiefly of sand and clay, the characteristic color of which is red, and which, although destitute in a great measure of organic remains, affords an abundant supply of gypsum and rock-salt. During the period occupied by this deposition, there are unequivocal indications of the commencement of an almost entire revolution in the forms of organic life. It is in this formation, in Connecticut, that Professor Hitchcock has discovered impressions of the feet of birds of gigantic size and curious structure. The tracks also of an animal supposed to belong to the *marsupial* or lowest order of *mammalia* have been discovered in the new red sandstone

of different portions of Europe; but from the absence of any definite traces beyond these foot-prints, no certain evidence of the remains of mammalia at this early period can be predicated.

"We have now," to use the expressive language of Dr. Mantell, "arrived on the shores of that ocean, of whose spoils the existing islands and continents are principally composed; the fathomless depths of the ancient seas are spread out before us, and the myriads of beings which sported in their waters, and lived and died in those profound abysses, remain, like the mummies of ancient Egypt, the silent, yet eloquent teachers of their own eventful history." During this period, several species of enormous *saurians*, reptiles, marine, amphibious, and terrestrial, of the lizard tribe, the *mososaurus, ichthyosaurus, plesiosaurus, megalosaurus, iguanodon, megatherium,* &c., ranged undisturbed over the land and inhabited the sea, deriving an ample sustenance from the unclaimed stores of vegetable and animal life by which they were surrounded, and leaving legible foot-prints of their existence, nature, and magnitude, but fortunately for the interests of humanity, transmitting to us no lineal representatives of their formidable dynasty.

To this, succeeds, over the northern portion of Europe, including the whole of England and a large part of France and Germany, and on the eastern portion of the United States, occupying the Atlantic border from New Jersey to Florida, and thence developing itself in a westerly direction over Alabama, Arkansas, and Missouri, the *chalk* formations, or *cretaceous system* of the geologist, resting upon a foundation of sand and clay, in its lower part, and consisting in general of a soft and earthy carbonate of lime, but occasionally presenting over large surfaces, an indurated mass of compact crystalline marble well adapted to ornamental architecture. The upper

portion of this formation, so extensively prevalent in Europe, seems to be wanting, or very imperfectly developed in the corresponding rocks of the United States. There are strong reasons for attributing its origin, at least in part, to the decay of pre-existing beds of coral; a microscopic analysis of large masses of this mineral in different portions of its structure exhibiting the presence of myriads of distinctly-formed shells and cases of marine infusoria and corals.

Many eminent geologists, however, while disposed to admit this hypothesis to a limited extent, and as adequate to account for the mineralogical phenomena presented by a portion of the cretaceous rocks, regard it as altogether insufficient to account satisfactorily, for the far greater surface of this extensive formation in both hemispheres; and attribute the origin of the calcareous and magnesian earths, as well as those composed of silex and alumine, to precipitation from igneous fluids from time to time thrown up from the interior of the earth, either as melted lava or in aqueous solution, or a mechanical admixture with water, through those vast fissures which are known so frequently to intersect the subjacent rocks. To whatever circumstances, however, we are to trace the origin of this important portion of the earth's surface, an accurate and scientific knowledge of its peculiar qualities, its location, extent, and boundaries, the adaptation of its various beds to the numerous purposes of agricultural and architectural economy, can scarcely fail to prove subservient in an eminent degree to the highest objects of civilized life.

Upon the chalk formation rests the series of the *tertiary* beds, which are distinguished from those of the secondary not less by their mineral character than by the marked differences in their organic remains. Instead of a consolidated mass of compact rocks, affording evidence of long-continued pressure and powerful metamorphic agen-

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cy, the tertiary strata for the most part present a succession of beds of gravel, clay, and sand, of mechanical origin, derived from the detritus of rivers, deposited in the beds of fresh-water lakes as well as oceans, and intermingled with volcanic matter. They contain ample evidences of a radical change in the conditions of the earth's surface; of the general prevalence of a lower temperature; of extensive alterations in the relative position of sea and land; of the existence in the eastern hemisphere of immense fresh-water lakes, analogous to those in our own continent; and of the operation of subterranean forces of immense power, and vast extent. An entire revolution in organic species succeeded in the order of events to which we have arrived. No species of shells common to those of the preceding formations have yet been discovered; the enormous reptiles which characterized the secondary era wholly disappeared, and were replaced by others more nearly corresponding to those which haunt the banks of modern tropical rivers and gulfs; and unequivocal indications of marine and terrestrial mammalia here first meet us. Deposites of plastic clay, sandstone in all its varieties, siliceous limestone, gypsum and freshwater, and marine marl, and rich alluvial loam are found variously intermingled, and resting at various depths below the surface, upon the beds of the secondary formation. The constituent elements of soils of the richest fertility and highest agricultural value, here abound in every portion of the earth; and it is upon that discriminating and thorough acquaintance with their various localities, extent, and characteristics, which this science alone can adequately give, aided by the clear discoveries and systematic researches of modern chymistry, that the enlightened agriculturist must depend for the ability to derive the greatest amount of practical power from the soil at his command.

Where the soil consists chiefly of clay, the incessant moisture and dampness arising from the retentiveness of this substance must be overcome by constant and systematic draining or neutralized by a plentiful and judicious admixture of other and more porous earths, aided by animal and vegetable manures. Where the prevailing constituent is sand, an opposite mode of treatment is requisite, in order to obtain the necessary supplies of water; and an infusion of clay and limestone, together with a process of irrigation, becomes indispensable to its fertility. The artificial combination of the different species of soils, in connexion with a plentiful supply of decomposed animal and vegetable matter, affords the richest materials for agricultural enterprise. But in order to effect this combination in the most judicious and effective manner, and to render it available as far as may be practicable under every variety of circumstances, the agriculturist must possess an accurate and discriminating knowledge of the component elements of his soil, at various depths from the surface; of its contiguity to other and different formations; of its chymical composition, susceptibilities, powers, and adaptations; and of the proportions of its different combinations best adapted to specific parts and courses of husbandry.

But it is unnecessary to pursue at greater length this train of investigation to be convinced that, considered in a merely economical point of view, the discoveries and deductions which geological science enables us to make from the enlightened perusal of the great volume of nature thus laid open to our view, are of the utmost importance and value to the well-being and advancement of the race. To the miner; to the agriculturist; to the architect; to the merchant; no less than to the statesman, the naturalist, the chymist, and the philosopher—do the lessons here written upon the adamantine tablets of crea-

tion commend themselves with a pertinency and force inferior to the claims of no portion of existing knowledge. All classes—all interests—identified with modern civilization, refinement, taste, and progress, find here the inexhaustible materials from which the structure of the social fabric is to be perpetuated, enlarged, and elevated, in harmony with the march of increasing knowledge, wisdom, and moral and intellectual power.

When, however, we expand our conceptions from material interests to an enlarged appreciation of the economy of our Being in all its relations; when from the circumscribed limits of mere utilitarian investigations, we pass to the wide domain of a higher philosophy—the developments of geology assume a magnificence, a grandeur and sublimity, equalled only by those ennobling records of infinite time and space, which the astronomer has unfolded to our astonished perception. In the contemplation of those vast eras of duration which are feebly signified to our senses by the successive results of periods embracing for their completion cycle upon cycle of ages, compared with which the few thousands of years which have elapsed since the creation of man marked the epoch of humanity, dwindle into utter insignificance; our minds are lost in the effort to grasp the conception, however inadequate, of that creative energy, which originated, and through such vast periods, and by such magnificent and incomprehensible displays of power, prepared for the habitation of intelligent beings, this terrestrial orb, itself but one among the least of those myriads of worlds which overspread infinity of space.

"No analogy," says Mr. Lyell, speaking in reference to the time which has elapsed since the Niagara river first began to drain the waters of the upper lakes, "can be found in the natural world to the immense scale of these divisions of past time, unless we contemplate the

celestial spaces which have been measured by the astronomer. Some of the nearest of these, within the limits of the solar system, as for example, the orbits of the planets, are reckoned by hundreds of millions of miles, which the imagination in vain endeavors to grasp. Yet one of these spaces, such as the diameter of the earth's orbit, is regarded as a mere unit; a mere infinitesimal fraction of the distance which separates our sun from the nearest star. By pursuing still further the same investigation, we learn that there are luminous clouds scarcely distinguishable by the naked eye, but resolvable by the telescope into clusters of stars, which are so much more remote that the interval between our sun and Sirius may be but a fraction of this larger distance. To regions of space of this higher order in point of magnitude, we may probably compare such an interval of time as that which divides the human epoch from the origin of the coralline limestone over which the Niagara is precipitated at the Falls. Many have been the successive revolutions in organic life, and many the vicissitudes in the physical geography of the globe, and often has sea been converted into land and land into sea since that rock was formed. The Alps, the Pyrenees, the Himalaya, have not only begun to exist as lofty mountain chains, but the solid materials of which they are composed have been slowly elaborated beneath the sea within the stupendous interval of ages here alluded to."

"The evidence of geological phenomena," observes Dr. John Pye Smith, in one of the notes to his admirable treatise on Scripture and Geology, "constrains us to the belief that our earth has existed—has been the seat of life—and has undergone many changes of its surface through periods of time utterly beyond human power to assign. That evidence is of distinct and independent kinds, chiefly derived from the appearances of stratifica-

tion, and the remains of animal and vegetable life; and to at least the most of those who have taken pains to become competently acquainted with its nature and variety, it produces the effect of an overpowering ocular and tangible demonstration."—"The remains of human beings, and of any vestiges of the arts and operations of man, are discovered only upon or in those surfaces and earthy masses which are demonstrably posterior to all regular geological deposites; and under circumstances indicating the human species to have been among the most recent products of the Creator's power."—"In no formation that can be called stratified, even of the newest tertiary beds, has anything human been discovered; and the formation even of those strata which are nearest the surface must have occupied vast periods, probably millions of years."—"The whole series of strata, from the earliest of them to the present surface of the globe, exhibits a body of evidence, in favor of this doctrine. Every stratum consists of a mass of earthy matters, which once formed the substance of rocks on elevated lands. These portions of the rocks have been separated for their parent masses, worn down, comminuted, transported often to great distances by the force of water, deposited, consolidated, elevated, and hardened. Operations of this kind have been repeated many times, homogeneously and heterogeneously, as to the mineralogical constitution of the masses; but the thickness, the lamination, the joints, and cleavage, and the imbedded remains of animal and vegetable beings, can not be contemplated with due attention, without producing a conviction stronger than words can express of periods of time amazing and overwhelming to the mind."—"Let me entreat a thoughtful person to meditate on the succession which we have thus rapidly and imperfectly reviewed. Let him represent to himself a series of earthy materials for the

most part dried and consolidated into hard rock, proved by the plainest evidences of the senses to have been sediments from mixture in water; carrying, in their texture and accompaniments, the equally manifest proofs of quiet, gradual, and slow deposition; altered at different and long-distant times by forces urging from below, often and perhaps usually of very slow and gradual action, but frequently by the intrusion of melted rock driven up with tremendous violence; and that the united thickness of the whole can not be less than five miles, but certainly, in extensive ranges, approaching to the double of that estimate. Let him ask, in each case, whence were those earthy materials derived? He will find that they have been worn away from the surfaces of antecedent and now underlying rocks and dry land. Let him, then, reflect upon the time requisite for this repetition of operations so prodigious, producing a series of many terms, requiring intervals of both repose and action, to which it is difficult for the imagination to soar. And let him consider whether he can conceive the possibility of those results having been effected in less periods of duration than such as bid defiance to our poor chronology." Mr. M'Culloch—an assiduous, sagacious, and eminently-qualified observer; a most extensive laborer in the field of practical geology and a zealous friend of revealed religion—assigns a period of at least *six hundred thousand years*, for the production and deposition of the carboniferous or coal-bearing *series*, of the sandstone formation alone. "And yet," he observes, "what are the coal deposites, and what the oldest sandstone, compared to the entire mass of the strata? If these views of the powers and the results of geological investigation are alarming to feeble minds, they tend to exalt that science in the estimation of those who neither fear to seek Truth, nor dread it when found."

It is easy for the most superficial mind to conceive the exertion by the Deity of that Omnipotence which, by a word, should speak into existence not only this planet of ours, but systems of worlds pervading all space and filling all immensity; and that, by the fiat of his will, he should impress upon every portion of that matter which presents itself to our view, its peculiar properties, appearances, and phenomena, whether of animal or vegetable life; of organic fossils; of alternating marine and terrestrial strata; of hill and valley, mountain, lake, and plain; of disturbance, derangement, contortion, and dislocation, similar in appearance and effects to such as we now perceive to be the invariable and necessary consequences of the long-continued operation of efficient causes pervading the whole economy of nature. We can neither assign bounds to the power of Omnipotence, nor undertake to prescribe the manner in which that power shall at any time be exerted. But in the legitimate exercise of those faculties of reason and judgment which he has conferred upon us, we are guilty of no presumption in inferring, from a comprehensive survey of those great laws which are impressed upon the constitution of the universe, as well of mind as of matter, that the appearances which present themselves on every hand to our view, participate in and are arranged conformably to those simple but majestic and eternal principles. When we discover upon the caps of the highest mountains of our existing continents, the entombed relics of myriads of insects, corresponding in structure and organic development, in all respects, with those which we know now to constitute the inhabitants of the ocean's profoundest abysses; when, at every stage of our progress from these elevated cliffs to their base, ... hume from their apparent sleep of ages, the im... remains of animals, vegetables, and minerals, the ... which have no existence in the most ancient ... of the historical period, and are utterly unknown

to the present order of things; when we survey, in every portion of the globe, the overpowering evidences of a series of convulsions, catastrophes, and general dislocation and disturbance of the subjacent surface; and trace over all, a long succession of formations, upon whose firm and consolidated beds, animal and vegetable life has for ages flourished and decayed; and finally, when we seek in vain for the remotest traces of man or his works, beyond the most modern of these myriad formations, each one of which must, so far as we can determine, either from reason, experience, or observation, have required centuries for its completion; we are no longer at liberty, in the rational and responsible exercise of the powers conferred upon us, to reject the irresistible testimony of our senses, our reason, and judgment, or to resort to the agency of a miraculous exercise of omnipotent energy, to enable us to "cut the gordian knot" of creation, and solve the difficult but clear problem of the past. We are to remember that, to the Deity, "a thousand years are but as one day;" that time and space have no existence in the counsels of the Infinite One; that in the formation, as in the preservation of the material world, those principles of order, of harmony, and of adaptation, which pervade all being, and without which we are utterly incompetent to form the remotest conception of existence itself, must necessarily prevail; and that, feeble and inadequate as may be our highest comprehension of the ultimate scope, and limited as is our knowledge of the extent and boundaries of those eternal laws, in accordance with which the universe holds on its majestic and magnificent course, from age to age, the segment of the vast and boundless circle of Providence, which is open to our view, presents no features at variance with or unconformable to the mighty whole.

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From among the numerous Recommendatory Notices which the Publishers received during the progress of the publication, we have only room to give the following:—

From D. MEREDITH REESE, A. M., M. D., *Superintendent of Common Schools in the City and County of New York.*

NEW YORK, Oct. 20th, 1845.

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D. M. REESE.

ALBANY, May 5, 1846.

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Mr. Stephens, the author of the above-named work, was engaged for several years in writing it. Its publication was commenced in London, in January, 1842, and concluded in August, 1844. The author closes the work in the following words:—

"I have now brought to a termination the task I had imposed upon myself in writing this work. If you will but follow the prescriptions I have given in it, for conducting the larger operations of the field, and for treating the various animals of the farm, and—not to mention the proper ploughing and manuring of the soil—as the practice of every farmer demonstrates the necessity of affording due attention to those most important because fundamental operations, if you finish off your fields in a manner indicating care and neatness—ploughing round their margins, and turning over the corners; if you keep your fences clean and in a state of repair—your fields free of weeds; if you give your stock abundance of fresh food at regular intervals in winter, and supply them with plenty of clean water on fresh pastures in summer; if you have the farm roads always in a servicable state, and everything about the steading neat and orderly; if you exhibit skill and taste in all these matters, and put what is called *a fine skin* on your farm, you will not fail to earn for yourself the appellation of a good and exemplary farmer; and when you have everything about you 'thus well disposed,' you will find, with Hesiod of old, that profitably, as well as creditably, for you 'shall glide away thy rustic year.'"

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